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Linking root water uptake, plant-hydraulic traits and transpiration dynamics of beech and spruce

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Motivation

Stomatal conductance and **capacitance** (tree water storage) can be variable across species. We observed “loose” stomatal closure combined with low capacitance in beech vs. “strict” stomatal closure with high capacitance in spruce. We include capacitance in a **soil-plant hydraulic model** and investigate the **sensitivity of plant hydraulic functioning** to its magnitude.

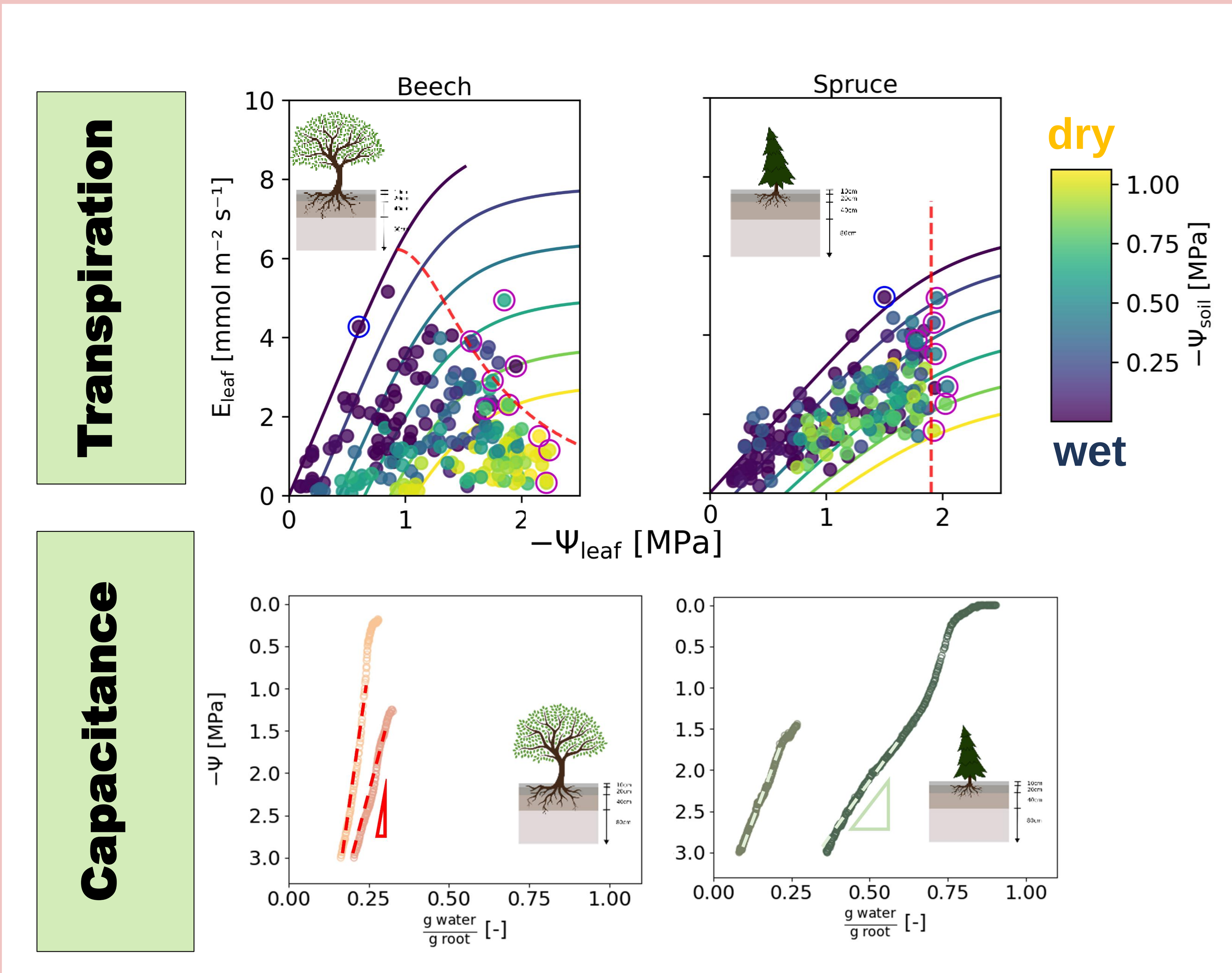

Figure 1: *Top row* - Beech allows **leaf water potentials (x-axis)** to drop further than spruce, leading to drier soils and stronger reductions in **leaf transpiration (y-axis)**. We hypothesize that beech stomata close (limit Ψ_{leaf}) when E/ Ψ_{leaf} starts to decrease (red-dashed curve), while spruce stomata close when Ψ_{leaf} approaches -1.8 MPa (red-dashed vertical line).
Bottom row – Beech roots tend to store less **water (x-axis)** and release it faster than spruce when the **tissue water potential (y-axis)** drops. Thus, spruce has higher capacitance than beech.

Soil-plant hydraulic model

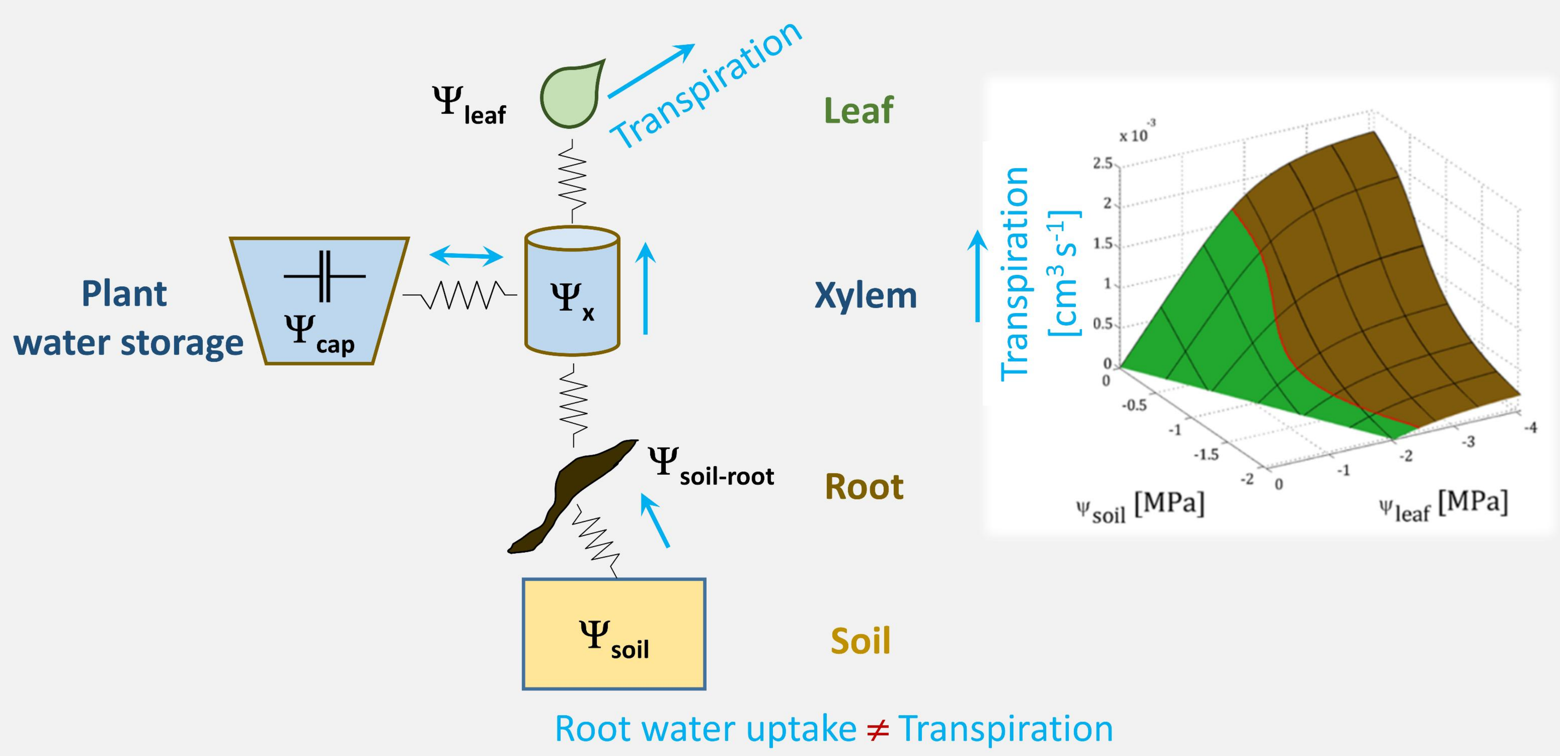

Figure 2: The soil-plant hydraulic model (*Carminati & Javaux 2020*) predicts the hydraulic gradient from the soil to the leaf required to transpire at a certain rate. Here, we include plant capacitance. Transpiration and root water uptake differ (which is commonly neglected) because water for transpiration is also sourced from capacitance (plant internal storage).

We compare model results for beech & spruce without capacitance (***Figure 1***) and with capacitance (***Figure 4***).

Root water uptake

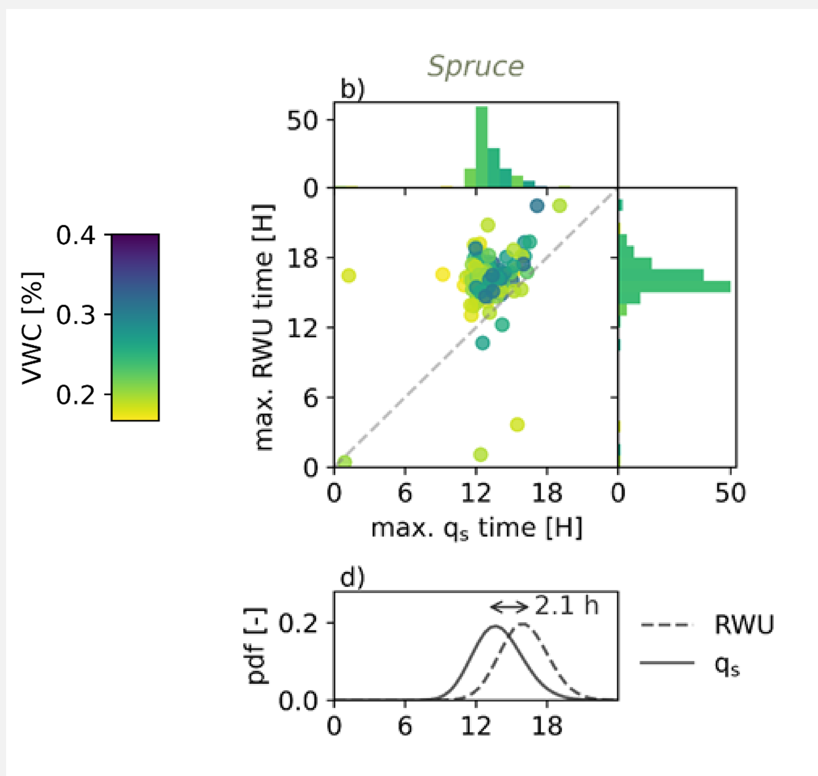

Figure 3: Timings of recorded daily **maximum in sapflow (x-axis)** of a spruce tree and **maximum root water uptake at 40cm depth (y-axis)** near the spruce tree. There is a consistent time lag of about 2 hours. The time lag occurs due to capacitance, as transpired water is sourced from plant water storage before root water uptake can supply water.

Effects of capacitance on soil-plant hydraulics

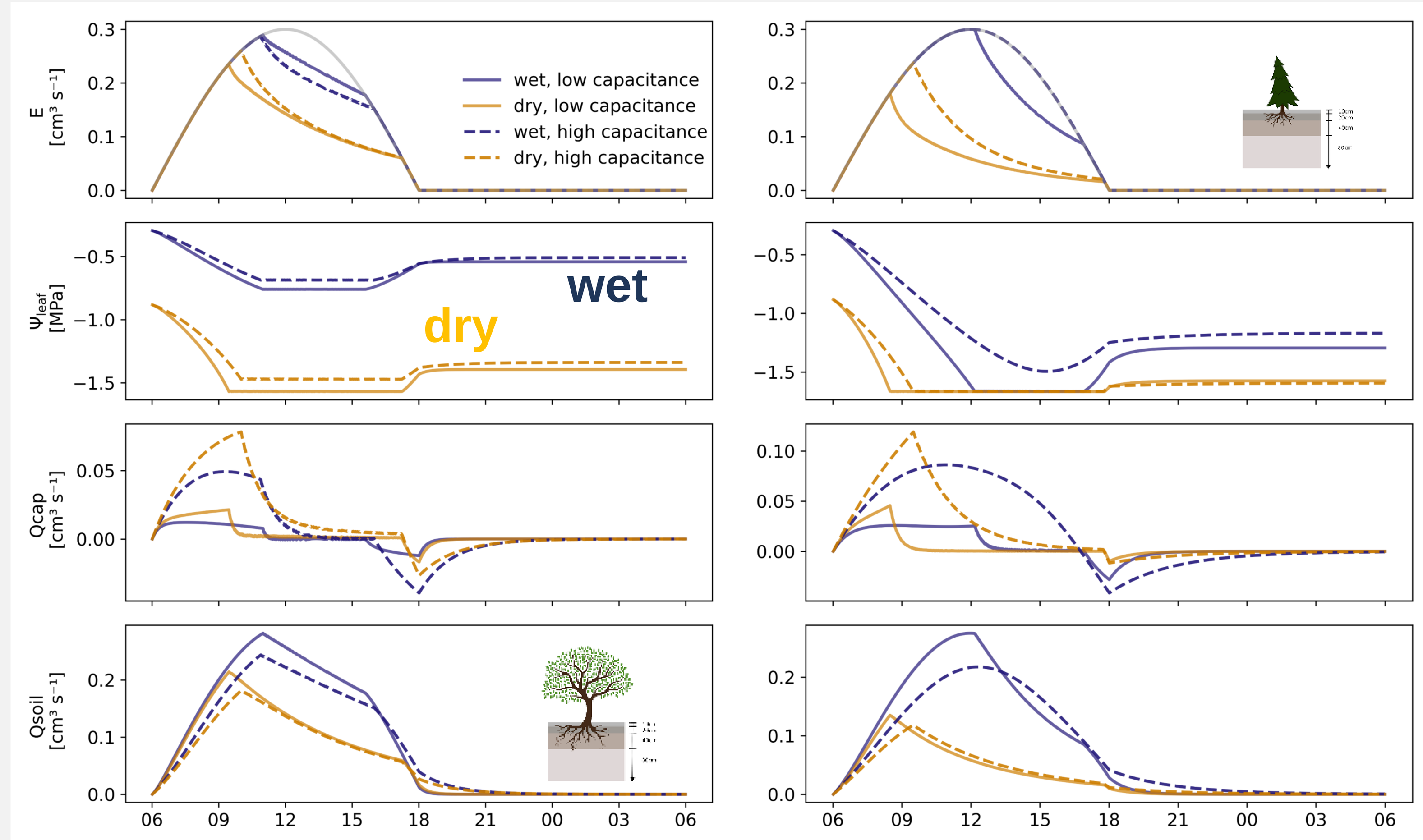

Figure 4: Simulated time series of transpiration (E), leaf water potential (Ψ_{leaf}), water flux sourced from plant water storage (Q_{cap}) and root water uptake (Q_{soil}), for beech (left – “loose” stomatal closure) and spruce (right – “strict” stomatal closure) for different levels of capacitance.

Conclusions

- Higher capacitance increases fluxes from plant water storage and dampens water potentials required to sustain transpiration
- Despite higher capacitance, spruce trees regulate transpiration more rigorously (*Martinetti et al. 2024*).
- Plants invest in “plastic” stomatal conductance strategies (beech) or capacitance (spruce) to maximize transpiration.

References

1. Carminati, Andrea, and Mathieu Javaux. “Soil Rather Than Xylem Vulnerability Controls Stomatal Response to Drought.” *Trends in Plant Science* 25, no. 9 (September 1, 2020): 868–80. https://doi.org/10.1016/j.tplants.2020.04.003
2. Martinetti, Stefano, Peter Molnar, Andrea Carminati and Marius G. Floriancic. “Contrasting the soil-plant hydraulics of beech and spruce by linking root water uptake to transpiration dynamics” *Tree Physiology* (to be published). https://doi.org/10.1093/treephys/tpae158

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