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Plant water storage: insights into a drought coping mechanism

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Plants in arid and semi-arid regions rely on their internal water storage to meet high evaporative demands. This water storage is crucial, allowing plants to open their stomata even when the soil cannot supply the necessary water fluxes. Plant usage of water storage allows for a time lag between transpiration and sap flow.

We model the plant hydraulics using both a hydraulic model and its electric analogue. Internal water storage is described by a pressure-volume curve, where the water storage capacitance depends on relative water content.

First, we show the advantages of using an electric analogue model. When the soil is considered an external factor with respect to the plant model, we find that leaf water potential ψ_L and soil water potential ψ_G must be treated independently, meaning that an effective driving potential $\Delta\psi = \psi_G - \psi_L$ yields inaccurate predictions regarding the water dynamics. The analysis of the electric analogue also yields a useful relationship between the plant traits (its capacitance and hydraulic conductivities) and the typical time scale of response to disturbances. Finally, a deeper understanding of the buffering role of the water storage is gained, by framing it as a frequency filtering problem.

The second main result is achieved by explicitly including soil water as part of the system by modeling it with the help of a capacitor. This two-tier capacitor structure (one for the soil and one for the plant water storage) elucidates the mechanism of time lag between transpiration and sap flow. Measurements from the Yatir Forest in Israel reveal a large time lag in the summer (dry season), while a much smaller lag exists in the winter (rainy season). Validating our model against these measurements produces estimates of both the season-dependent capacitance and the relative internal plant storage.

A better understanding of the plant water storage mechanism is essential in the face of climate change and an increasing number of ecosystems threatened by drought. The strength of our modeling approach lies in the clarification of the fundamental processes that play in plant survival. Our predictions are instrumental in determining plant traits that are hard to measure directly, and in deriving plant water dynamics under drought.