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Characterizing plant hydraulic behaviour under drought stress using vegetation modelling

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Droughts have emerged as the primary driver of forest disturbances across Europe in the 21st century, significantly impacting both tree growth dynamics and mortality rates. Tree species are differently affected under drought, and these differences are related to species-specific plant hydraulic traits that govern water storage, hydraulic conductivity, and stomatal regulation. However, quantifying variability in these hydraulic traits across sites, species, and time remains challenging, as site measurements have historically rarely been comprehensive enough to assess the evolution of plant hydraulic behavior under drought stress. New continuous, high temporal resolution observational plant hydraulic data paired with process-based plant hydraulic modelling opens an opportunity to address this gap, by providing a framework to test and quantify theories based on first principles across species and sites.

In this study, we apply the terrestrial biosphere model QUINCY, augmented by a recently developed plant hydraulic architecture module, across three eddy covariance sites in Germany covering broadleaved forest species (Aplern, Hainich, and Hartheim). The model is parameterized for three common temperate tree species present at the aforementioned sites. We constrain QUINCY across these species and sites using 30-minute resolution stem water potential measurements collected during the summer and autumn of 2023. Our results show that two groups of model parameters explain most of the simulated plant water potentials: parameters controlling plant water uptake from soil (plant ability to extract water from soil and the root distribution), and parameters regulating stomatal sensitivity to pre-dawn leaf water potential. Across species, we find ash to be more drought resistant than beech and hornbeam, as it closes its stomata earlier than other species under similar levels of drought stress, and it is characterised by a higher hydraulic capacitance per unit stem volume. Our study demonstrates how integrating the new generation of *in situ* plant hydraulic observations into vegetation models can facilitate the quantification of species-specific hydraulic parameters, effectively reducing uncertainty in, and providing robust constraints on, modelled responses to drought.