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Optimality of plant water use strategies – an eco-hydrological perspective

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In most ecosystems, water is a limiting factor for vegetation for at least a part of the growing season. This raises the question: how can plant use the limited available water in the most effective way – increasing their chances of survival and improving their long-term fitness? This question is complicated by two factors: one is purely biological – transpiration and carbon (C) uptake are inherently linked via the stomatal pores, so increasing growth (and fitness) requires consuming more water – and the other is climatic – water availability changes unpredictably due to random rainfall occurrences. Because of the transpiration-C uptake link, plants using water intensively to grow fast may worsen their own water stress by depleting soil water faster than it is replenished. Because of the climatic factors, water use strategies are expected to vary along climatic gradients. Here we ask how plants should use water during extended dry periods and along wide climatic gradients to maximize their fitness.

We start from the hypothesis that plants optimally regulate transpiration to maximize C uptake. This optimization problem can be addressed at different time scales – from the sub-daily scale at which atmospheric conditions change rapidly without significant change in soil water storage; at the dry down scale at which soil moisture varies significantly and drives the development of water stress; at successional to evolutionary time scales to investigate how hydro-climatic variability selects for specific plant hydraulic traits and water use strategies. Based on the optimization model results, plant water use strategies are defined and their success in a changing environment is assessed. In some cases, different strategies are found to yield similar plant fitness in the long-term, thus explaining why species with contrasting traits may coexist under the same climatic conditions.