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Do plants follow a profit maximisation approach during drought?

Manon Sabot, Martin De Kauwe, and Andy Pitman

ARC Centre of Excellence for Climate Extremes and Climate Change Research Centre, University of New South Wales, Sydney, Australia

Climate change is expected to increase the frequency, intensity, and duration of future droughts with many associated environmental and socio-economic consequences. Large-scale droughts have recently been implicated as the driver behind widespread reports of tree mortality across a variety of climates and vegetation types. Yet, projecting the impact of future droughts on the vegetation using state-of-the-art land-surface models is problematic as models perform poorly during periods of water stress. Most models employ empirical functions to limit the exchange of carbon and water under water-stressed conditions. However, the validity of these approaches has been called into question as the data to support them is lacking. To address this issue, land-surface models have begun to utilise sophisticated treatments of plant hydraulics. This added process mechanism comes at a computational cost and the need for additional parameterisation. More recently, Wolf et al. (2016) and Sperry et al. (2017) proposed profit maximisation approaches where the stomata act to optimise leaf gas exchange against the cost of maintaining hydraulic function (e.g. sap flow). Here, we implement a parsimonious profit maximisation (photosynthetic gain – hydraulic cost) approach within the Community Atmosphere Biosphere Land Exchange (CABLE) model, CABLE-SOPHA (Stomatal Optimisation of Photosynthesis and Hydraulics Approach). We evaluate CABLE-SOPHA across a suite of FLUXNET sites, testing whether the vegetation exhibits behaviour consistent with an optimal profit maximisation approach. We further probe whether such an approach works during climate extremes, or whether plants require additional acclimation processes. In particular, we test the optimisation approach for short- versus long-term drought events and whether the departures from the observed fluxes can be attributed to structural acclimation (i.e. the turnover of leaves/branches) or to the need for non-stomatal limitations (i.e. limitation of the biochemistry). We finally exploit insight from this optimisation approach to identify a roadmap that will be used to examine the impact of future droughts on vegetation.