Title: Where do trees' source water during drought? Inverse modeling reveals drought strategies coordinating water-uptake depths with above ground traits

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Project Abstract: Forests are critical to the terrestrial carbon and water cycle, but droughts are predicted to increase in frequency and intensity, threatening forest function through lower productivity and increased mortality. Identifying species differences in drought response is critical to predicting the extent of this threat. Species strategies for handling water stress have been explored almost entirely in terms of above-ground responses, but not how water stress might be avoided or tolerated through differential access to the highly dynamic below-ground water environment. This is especially challenging to study in tropical forests with hundreds to thousands of tree species. Here we present a first instance of a well-validated, inverse model that estimated trees' water-uptake depths scaled up to scores of co-existing tree species. We hypothesized that trees' growth dynamics was a function of a species' rooting profile (an unknown), and the dynamics of plant water potential along that profile plus an error term.

We tested this approach at the seasonally dry tropical forest of BCI, Panama by estimating rooting profiles for 51 tree species that best explained their 25 yearlong records of growth dynamics (1990-2015). To obtain reliable, concurrent estimates of water potential and plant available water throughout the rooting zone we locally parameterized DOE's Energy Exascale Earth System Model (E3SM) - Functionally Assembled Terrestrial Ecosystem Simulator (FATES). We calibrated it against observations of soil moisture dynamics by depth, evapotranspiration and stream runoff.

Forced with local climate data, we then ran ensemble simulations of E3SM-FATES over 1985-2015. We calculated species' mean water-uptake depths as a function of best-fit species-specific rooting profiles as well as water potential and plant available water in each soil layer up to 13 m.

The 51 species showed diverse water-uptake depths (0.1-13 m). For a subset of species with data on xylem sap ^{2}H concentration indicating their water-sourcing depths model matched data well. This match was especially better when we used species-specific Turgor Loss Point as the limit to water-uptake. We also found that species with deep water access were associated with drier sites within the plot, as well as, across the Isthmus of Panama, had larger Leaf Mass to Area ratio, higher leaf-level hydraulic conductivity, and larger safety margin based on capacitance. These results suggest that drought strategies of co-existing tree species are an integration of well-coordinated above- and below-ground traits suited to their different water environments.