Title: On Drought Resilience among Tree Species

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Project Abstract:

Water is the principal regulator in biosphere-atmosphere interactions. High-frequency observations at a steep hillslope in the Mediterranean climate of northern California show that different proximate evergreen species have very different transpiration seasonality, with Pacific Madrones showing maximal daily transpiration in the dry summer season (Link et al. 2014). We hypothesize that the tree roots at the site have access to a deep store of water, as the water table some 20 meters below the surface exhibits very dynamic fluctuations with every rain storm. With DOE support, we have developed a stochastic parameterization of hydraulic conductivity that takes into account preferential flow through weathered bedrock (Vrettas and Fung, 2015), and applied the Richards Equation with the new parameterization to investigate the impact of subsurface water storage capacity (especially in the weathered bedrock) and rooting structure on the timing and magnitude of transpiration (Vrettas and Fung, 2017). The results show that it is the root mass below 4 meters that access the moisture in the weathered bedrock.
We have analyzed USDA Forestry Inventory and Analysis DataBase (FIADB) and mapped the spatial distribution of the 98 tree species in California. Our analysis shows tree mortality during the 2012-2016 drought does not map onto precipitation deficits for the period. Of the two most abundant tree species, Douglas Firs (14% of trees surveyed) experienced higher summer temperature anomalies and greater precipitation deficits than White Firs (13% of trees surveyed). Yet Douglas Firs have a mortality rate of 11% compared to 22% for White Firs. The mortality-weighted mean precipitation anomaly was -12.2 mm/month for Douglas Firs and -2.7 mm/month for White Firs, suggesting that Douglas Firs are more resilient to precipitation deficits.

We have further mapped the distribution of the tree species onto a geologic map of California. Douglas Firs are found predominantly in sedimentary rocks, while White Firs are found on plutonic rocks. Coupled with the fact that Douglas Firs have tap roots and White Firs have shallow, wide-spreading root systems, we hypothesize that sedimentary rocks, which have greater porosity than plutonic rocks, have a greater moisture storage in the subsurface, and that the moisture is accessed by the tap roots of the Douglas Firs. We thus demonstrate the interplay between climate and lithology, and show that deep water stores accessible to deep roots are not unique to the research site, and could explain differential resilience to droughts and insect infestations across a landscape.