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Plant Hydraulic Trait Trade-offs and Species Invasion Dynamics in Moist Tropical Forests

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It has been postulated that in areas with seasonal precipitation, episodic droughts or strong soil moisture gradients, fundamental trade-offs among plant hydraulic traits are a key driver of coexistence between a diversity of plant functional types (PFTs). However, strong evidence from direct observations for such trade-offs has been elusive, which may be a consequence of sampling design and data aggregation in meta-analyses. We evaluated this assertion by using a cohort-based terrestrial biosphere model with a mechanistic representation of water transport, the Ecosystem Demography model (ED2-hydro), to explore how and where the trade-off between hydraulic efficiency and safety may emerge within a forest ecosystem. Hydraulic efficiency and safety were evaluated in terms of xylem conductivity (Kx) and vulnerability to cavitation (xylem-P50), respectively. We performed a controlled set of tropical forest simulations using local meteorological drivers and soil conditions from Barro Colorado Island, Panama and various combinations of Kx and xylem-P50. We also introduced into a mature forest at low densities an invading juvenile PFT with a hydraulic strategy differing from the native PFTs to determine both where competition governed by the efficiency vs. safety trade- off manifests itself and the conditions that allow successful invasion. ED2-hydro predicts that a strong efficiency vs. safety trade-off exists at the individual scale for trees that are in direct competition. Moreover, the Kw and xylem-P50 trait space is broad, and hence the trade-off is apparently masked when observations of numerous species within an ecosystem or biome are included without also considering the traits of the observed individual's immediate competitors. For invasions of non-native PFTs to be successful, this trade-off also depends on the developmental stage of the gaps in which the trees are growing. Invaders that germinate and become seedlings in closed-canopy patches of the forest are unsuccessful. But, invaders with superior hydraulic strategies (i.e. Kw and xylem-P50 combinations) that germinate in newly created forest gaps are successful in establishing and either coming into coexistence with the native PFTs or competitively excluding them. Therefore, our results demonstrate that this modeling framework can be used to bracket the vulnerability of forests to invaders when disturbance regimes change. We also recommend a series of new field measurements to test the hypotheses proposed by our results.