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Extrapolating carbon dynamics of tropical dry forests into future climates: improving simulation models with empirical observations

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Tropical dry forests occur in areas with warm temperatures and a pronounced dry season with little to no rainfall that lasts 3 to 7 months. The potential area covered by this biome is vast: globally, 47% of all forest occurs in tropical and subtropical latitudes, and of all tropical forests approximately 42% are classified as dry forests. Throughout the last several centuries, the area covered by tropical dry forests has been dramatically reduced through conversion to grazing and croplands, and they are now considered the most threatened tropical biome. However, in many regions, tropical dry forests are now growing back.

There is growing concern that this recovery process will be strongly impacted by climate variability and change. Observations show that climate is changing in the seasonal tropics, and climate models forecast that neotropical dry forests will receive significantly less rainfall in the 21st century than in the 20th century. Rates of nitrogen deposition are also changing rapidly in this sector, and the fertility of some soils may still be recovering from past land use.

We are engaged in several efforts to understand how water and nutrients limit the productivity of these forests, including manipulative experiments, modeling, and investigation of responses to natural climate variability. In 2015, at a well-characterized site in Guanacaste, Costa Rica, we established a full-factorial fertilization experiment with N and P in diverse mature forest stands. Initial responses highlight stronger ecosystem sensitivity to P addition than to N addition. Intriguingly, pre-experiment numerical simulations with a mechanistic ecosystem model had indicated the reverse. Work is ongoing to use field observations to better represent critical processes in the model, and ultimately to improve the model's sensitivity to nutrients and water. In addition, in 2016, we established a full factorial nutrient addition and drought experiment in plantations. Thus far, soil moisture has been successfully reduced in the drought treatments.

Finally, we are investigating the impact of an extreme climatic event, the 2015 drought, on the productivity of this forest. The fingerprint of the drought on tree mortality is very strong. We found that plot-level mortality rates were two to three times higher during the drought than before the drought, and varied from 0 to >50% among species. In contrast to observations at moist tropical forests, tree size had little influence on mortality. In terms of functional groups, mortality rates of evergreen oaks growing on nutrient-poor soils particularly increased during drought. However, elevated mortality rates were not clearly correlated with commonly-measured traits like wood density or specific leaf area. In addition, trees that died during the drought tended to have smaller relative growth rate prior to the drought than trees that survived the drought. Mechanistic models are able to simulate stand-level mortality following the drought, and model-data comparison highlights different tree hydraulic strategies that can mitigate drought effects.