Characterization of Soil Carbon Cycling Across a Tropical Forest Rainfall Gradient for a Dry Down Experiment

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Background/Question/Methods
Soil carbon (C) dynamics in tropical forests remain a large source of uncertainty in Earth system models. Understanding drivers of tropical forest soil C fluxes, including root dynamics and nutrient effects, could greatly improve our ability to predict feedbacks to climate change. We assessed seasonal variation and environmental drivers of soil C pools and CO2 fluxes for 15 humid tropical forests across rainfall and soil fertility gradients in Panama. Soil respiration was surveyed 4x over the wet and dry seasons for one year at each site using four 50-m transects. Air temperature, soil temperature, and soil moisture were measured concurrently with automatic probes. Also, soil C stocks, root biomass, and extractable nutrients were measured for 0 – 100 cm depths at a broader set of 48 sites. These measures serve as baseline data for a rainfall exclusion experiment that is in the construction phase at 6 of the sites across the rainfall gradient. The drying experiment will start during the wet season of 2018 (April).

For baseline data, predictors of soil C stocks and root biomass were assessed across the gradient. For soil CO2 fluxes, mean annual precipitation (MAP), soil fertility, and time/season were assessed as predictors using repeated measures MANOVA (n = 4 time points), using similar analyses for air temperature, soil temperature, and soil moisture. Significant interactions between MAP and time were explored using post-hoc analyses of Wet:Dry season CO2 flux ratios (n = 15), and stepwise models were used to identify predictors of these ratios. Air temperature, soil temperature, and soil moisture were also assessed as predictors of soil CO2 fluxes (n = 200 transects). Statistical significance was p < 0.05.

Results/Conclusions
Soil C stocks were weakly related to MAP ($R^2 = 0.11$), and much more of the variation was explained by including root biomass, soil clay content, and extractable base cations in a structural equation model ($R^2 = 0.48$). There were significant effects of seasonality on soil CO2 fluxes, with an interaction between MAP*time. This interaction appeared to be driven by shifts in the magnitude and direction of the seasonal effect at the extremes of the rainfall gradient. In particular, the Wet:Dry season CO2 flux ratios in the driest sites was $2.25 \pm 0.23$ (i.e. greater flux during the wet season), versus $0.81 \pm 0.09$ in the wettest site (i.e. greater flux during the dry season). The best model to predict Wet:Dry season CO2 flux ratios included soil C, resin phosphorus (P), and extractable potassium ($R^2 = 0.65$), with resin P the strongest univariate predictor ($R^2 = 0.44$). Overall, air temperature, soil temperature, and soil moisture measures together predicted 26% of the variation in soil CO2 fluxes. These results show significant seasonality in soil respiration across this tropical rainfall gradient, and illustrate that forests with different baseline MAP and soil moisture can have opposite responses to drying. Also, the magnitude of the seasonal shift appeared related to soil phosphorus availability. These results suggest that soil respiration responses to regional drying in tropical forests are likely to vary according to local MAP, and that rock-derived nutrients may provide a control over soil C stocks and fluxes.