Into the deep: variability in soil microbial communities and carbon turnover along a tropical forest soil depth profile

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Project Goals: This Early Career research examines the genomic potential and expression of tropical soil microorganisms as they experience shifts in soil temperature, moisture, and depth and oxygen availability. By also tracking the degradation and fate of organic carbon compounds, this work will increase the accuracy of predictions about how microbial processes affect whether organic carbon is retained or lost from tropical systems. The mechanistic understanding produced by this research will directly benefit attempts to improve the predictive capacity of mathematical models that forecast future tropical soil carbon balance.

Tropical forest soils store more carbon (C) than any other terrestrial ecosystem and exchange vast amounts of CO_2, water, and energy with the atmosphere. Much of this C is leached and stored within deep soil layers, but we know exceedingly little about the fate of this C or the microbial communities that drive deep soil biogeochemistry. From data that do exist, most organic matter (OM) in tropical soils appears associated with mineral particles, suggesting deep soils may provide greater C stabilization due to organo-metal co-precipitation and mineral-surface interactions. However, few studies have evaluated sub-surface soils in tropical ecosystems, the turnover times of deep soil C, and sensitivity of this C to global environmental change.

To address this critical research need, we quantified C pools, microbial communities and soil radiocarbon turnover times in bulk soils and soil fractions [free light (unprotected), dense (mineral-associated)] from 0-140 cm in replicate soil pits in the Luquillo Experimental Forest, Puerto Rico. Unsurprisingly, we found soil C, nitrogen, and root and microbial biomass all declined exponentially with depth; total C stocks dropped from 5.5 % at the surface to <0.5% at 140cm depth. Soil OM ^{14}C and mean turnover times were variable across replicate horizons, ranging from 3-1500 years at the surface (0-20 cm), to 5000-40,000 years at 140 cm depth. Soil C in the mineral associated fraction was much older than the free light fraction C, which reflected modern ^{14}C at all depths. In comparison to temperate deciduous forests, these ^{14}C values reflect far older soil C, and OM decomposition that highly favors free light C pools, even at depth. While previous work suggests these low C tropical subsoils contain small but metabolically active microbial communities at depths of ~100cm, these organisms appear highly OM limited, and preferentially degrade recent inputs.

In the coming half century, tropical forests are predicted to see a 2 – 5 ° C temperature increase and substantial differences in rainfall amount and timing. The data described here represent baseline data for a site now undergoing a 4°C warming experiment; upcoming research will examine soil C storage and mean residence times during and post-warming to improve numerical models of ecosystem warming effects in tropical forests.

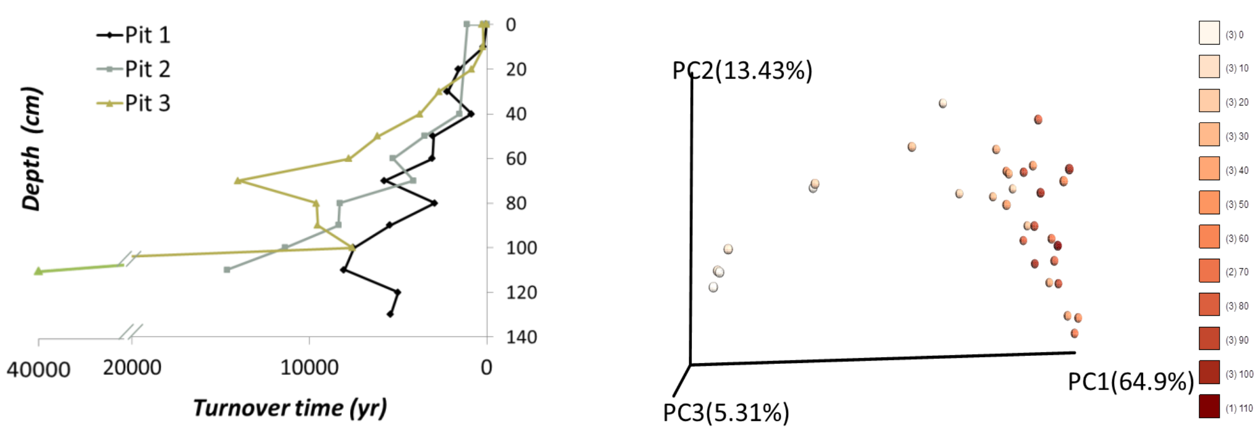

Fig 1. Left: $\Delta^{14}C$ turnover times increased significantly with depth, reaching up to 40,000 yrs in some of the deepest samples. Right: PcoA ordination highlighting the distinction between surface soils and those below the active root zone (using weighted Unifrac distance).

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