Climate and parent material controls on the composition of soil organic matter and microbial community

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Soil organic matter (SOM) plays a fundamental role in terrestrial biogeochemical cycling. Yet long-term responses of SOM, a significant carbon reservoir on the earth's surface, to environmental perturbations remain uncertain largely due to complex feedback processes among climate, parent material, and biota at landscape scale and intimate interactions among diverse soil microbes, organic compounds, and mineral particles at microscopic scale. Moreover, little is known about the factors controlling the composition of soil microbial community whose metabolism directly relates to SOM dynamics.

To assess the influence of climate and parent material (and its weathering products) on the composition of SOM and microbial community, we studied a series of undisturbed tropical forest soils developed on two contrasting parent materials, acidic metasedimentary vs. ultrabasic igneous rock, along a climate gradient on a mountain slope (altitude range: 700-2700m) in Borneo. To examine SOM composition of surface mineral horizons, we separated physically- and biochemically-distinct fractions by density: low-density plant detritus fraction easily separable from soil minerals (f-LF), low-density materials strongly associated with minerals (m-LF), and high-density fraction (HF) consisting of microbially-processed organic matter strongly associated with minerals. We also characterized microbial community composition of bulk soils from the surface and deeper horizons using phospholipid fatty acid (PLFA) biomarkers that are microbial cell membrane constituents having chemical composition unique to different broad taxonomic groups.

With increasing altitude (mean annual temperature from 24 to 12^{o}C with roughly constant rainfall), C standing stocks in surface mineral horizons on both parent materials increased from 2.6-2.8 to 5.4-7.5 kg m^{-2} with progressively greater proportions partitioned to m-LF and, to less extent, f-LF. SOM stocks in HF remained unchanged along the altitudinal gradient. These results suggest that two LF pools are more labile and are more sensitive to the altitude-induced, long-term climate difference than the HF pool, which is protected by the mineral matrix against microbial attack. The C:N ratios of HF on metasedimentary rock increased with altitude (11 to 17) while those on ultrabasic rock remained essentially constant (14-15), implying interactive influence of altitude and parent material on stoichiometry perhaps due to the contrasting mineralogies (phyllosilicate- vs. goethite-rich) weathered from the two parent materials.

PLFA analysis showed that soil C:N ratio and N content significantly correlated with fungi:bacteria ratio and, within bacteria, gram+:gram- ratio (r^2=0.5-0.7) across all sites and depths. The soils at lower altitudes (i.e. under warmer climate) and deeper horizons (i.e. lower litter inputs) contained less amounts of C and N with lower C:N ratios and strong mineral protection, which likely represent poor resource environment for microbes. In such environment, microbial community appeared to shift towards bacteria (particularly gram+ ones) dominance over fungi perhaps due to bacteria's capability of rapid growth/dormancy. Principle component analysis using all of the microbially-derived PLFA showed that parent material had at least as strong control over the community composition as altitude. Soil C:N ratio and C content showed marginal significance in explaining the variation in the primary axis derived from the analysis.

In summary, SOM stocks and its partitioning to the density fractions were mainly controlled by altitude (climate), while its stoichiometry was influenced by both altitude and parent material. These differences in stock, degree of mineral association, and chemistry of SOM appeared to control the microbial community composition. The causal linkage between SOM, microbial community, and the maintenance of tropical forest ecosystem needs to be substantiated by future work.