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Revisiting the terrestrial carbon cycle: New insights from isothermal microcalorimetry

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Energy is continuously transformed in environmental systems through the metabolic activities of living organisms. In terrestrial ecosystems, there is a general consensus that the diversity of microbial metabolic processes is poorly related to overall ecosystem function because of the inherent functional redundancy that exists within many microbial communities. Here, we propose a conceptual ecological model of microbial energetics in various terrestrial ecosystems (e.g. Scandinavian arable systems or temporarily flooded systems in South East Asia). Using isothermal microcalorimetry, we show that direct measures of energetics provide a functional link between energy flow and the composition of belowground microbial communities at a high taxonomic level. In contrast, this link is not apparent when carbon dioxide (CO_2) was used as an aggregate measure of microbial metabolism. Our results support the notion that systems with higher relative abundances of fungi have more efficient microbial metabolism. Furthermore, we suggest that the microbial energetics approach combined with spectroscopic and aqueous chemical measurements is a viable approach to determine the effect of energy release from organic matter on metal(loid) mobility in soils and sediments under anaerobic conditions. We advocate that the microbial energetics approach provides complementary information to soil respiration for investigating the involvement of microbial communities in belowground carbon dynamics. Our results indicate that microbial metabolic processes are an essential constituent in governing the terrestrial carbon balance and that microbial diversity should not be neglected in ecosystem modeling. Quantification of microbial energetics incorporates thermodynamic principles and our conceptual model provides empirical data that can feed into carbon-climate based ecosystem feedback modeling. Together they disentangle the intrinsically complex yet essential carbon dynamics of soils to address important issues such as climate change.