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Deciphering the Complex Interactions Between Litter Inputs and Microbial Responses in Modulating Long-Term Soil Organic Matter Dynamics

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Natural climate solutions that focus on increasing carbon in forests rely on the potential for additional carbon that may be incorporated into soil organic matter (SOM). The fate of soil carbon in temperate forests remains uncertain due to the complex role of microbes and their regulation of carbon flows in soils, especially with the addition of extra added litter. We identified comprehensive molecular-level evidence that revealed shifts in SOM composition and microbial communities after thirty years of added litter in a temperate deciduous forest. Chronic litter addition failed to add new soil carbon after thirty years and correlated with reorganization in microbial community composition and altered carbon use. Excluding detrital inputs decreased soil carbon content, resulted in enhanced SOM decomposition and shifts towards specific bacterial groups (such as oligotrophs) that can utilize less energetically favorable carbon substrates that are typically more recalcitrant. Nuclear magnetic resonance methods also confirmed changes in SOM biogeochemical trajectories with litter manipulation. Radiocarbon analysis of both soils and microbial biomass showed that microbes changed their carbon acquisition strategies in responses to long-term litter changes. Collectively, we found that microbial communities shifted in composition, altered carbon use strategies, and traits, which aligned with changes to the molecular composition of SOM. This work provides molecular-level insight on the limited potential for temperate mesic forests to sequester additional carbon and further highlights the critical need for long-term data that can better inform management strategies to protect soil carbon resources in forests. As well, these findings further illuminate the need to study these responses more holistically across forest types as ecosystem-specific properties are strongly linked to soil carbon biogeochemical trajectories. Finally, our work emphasizes that carbon biogeochemical cycling in forests is sensitive to changes in litter quality and quantity, as induced by climate change, and these responses are long-lived and are exacerbated over time.