Resolving Conflicting Physical and Biochemical Feedbacks to Climate in Response to Long-Term Warming

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Project Abstract

Microorganisms mediate soil carbon (C) cycling cycling in soils as they warm over the long term, and several mechanisms mediate the warming effects on microbial physiology and climate feedbacks to the atmosphere. Microbial C use efficiency (CUE) and physical protection have emerged as major controls of microbial C processing and soil organic matter (SOM) loss and stabilization. In the Harvard Forest long-term Soil Warming Study, soils have been heated 5 °C above ambient temperature for 27 years. During this time, soils have lost almost a third of their C, which is associated with reduced substrate quantity and quality. Here we hypothesized that long-term warming reduces physical protection and CUE. We further hypothesized that long- term warming would reduce the temperature sensitivity of CUE and its components, growth and respiration. Subsamples of bulk soil at optimal moisture (~10% gravimetric) were separated into macroaggregate (250-2000 µm) and microaggregate (<250 µm) fractions. Substrate availability, microbial process rates and measures of physical protection were measured at 15 and 25 °C. Microbial CUE was determined using a substrate-independent, ^{18}O-isotope labeling method ($H_2{}^{18}O$) that quantifies the amount of ^{18}O incorporated into microbial DNA after incubation for 24 hours. We found that long-term warming reduced substrate availability (soil C and N, enzyme activity), but did not affect physical protection (*i.e.*, occluded or mineral associated SOM). Warming showed little effect on CUE, because it reduced both growth and respiration. However, CUE was reduced more at 25 °C than at 15 °C, driven by increased respiration. Long-term warming rendered CUE and its components less temperature sensitive in macroaggregates but not in microaggregates. These findings suggest that microbial thermal adaptation to climate warming occurs more among the soil fractions that are already vulnerable to degradation. We also found that physically protected C inside soil aggregates was not as degraded as inter- aggregate C (Scanning Transmission X-ray Microscopy and X-ray Raman Scattering). Analyses from the trait-based model MIMICS (Microbial-Mineral Carbon Stabilization Model) suggest that chronic warming effects on soil C were more similar to observed values when adding microbial biomass to the function of SOM physical protection. Microbial acclimation to long- term warming seems to be mediated by physical protection, potentially limiting the self- reinforcing effects of warming to the atmosphere. Our findings demonstrate the need to include physical and biochemical factors for microbial thermal strategy in Earth system models to improve predictions of soil C feedbacks to the climate system.