



Microbial adaptation to temperature increases the vulnerability of carbon stocks in Arctic and Boreal soils to climate change

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There are concerns that global warming may stimulate decomposition rates in soils, leading to a substantial release of CO₂ to the atmosphere, and thus accelerating rates of 21st century climate change. However, there is growing recognition that adaptation of soil microbial communities to changes in their prevailing thermal regime may alter the potential rate of carbon release. Critically, recent studies have produced conflicting results in terms of whether adaptation of soil microbial communities to temperature reduces (thermal acclimation) or enhances (enhancement) the direct effects of temperature changes on decomposition rates. This lack of understanding adds considerably to uncertainty in predictions of the magnitude and direction of carbon-cycle feedbacks to climate change.

Investigating the impacts of adaptation to temperature is currently only possible in controlled laboratory experiments, in which fluctuations in substrate availability can be minimised. We developed a approach which involves incubating soils at 3°C above mean annual temperature (MAT), until respiration rates stabilise, then cooling by 6°C (MAT -3 °C) and determining the potential for respiration rates to recover during extended exposure to lower temperatures. Our approach avoids the issues associated with substrate depletion in warming studies, but still tests whether adaptation enhances or reduces the direct impact of temperature on microbial activity. In contrast to many other studies, our initial research clearly demonstrated enhancement in Arctic soils. Here we present results from a new project which has extended the approach to soils sampled from contrasting Arctic, Boreal, temperate, Mediterranean and tropical ecosystems. This study represents one of the most extensive investigations undertaken into the potential for thermal acclimation, and/or enhancement, under contrasting environmental conditions. We also attempted to disentangle the mechanisms underlying the observed responses by quantifying changes in microbial biomass, microbial community structure, mass-specific activity, carbon-use efficiency, and the activities of enzymes involved in the break-down of labile versus more recalcitrant compounds.

Our results from temperate, Mediterranean and tropical soils generally show little evidence of thermal acclimation, but responses were dependent on soil type and the temperature range investigated; at low temperatures and from organic soils, further evidence for enhancement was produced. The lack of evidence of acclimation suggests that there remains the potential for C losses from soils in temperate and tropical areas as the climate changes.

Furthermore, results from incubations from Boreal and Arctic soils showed clear enhancement. This suggests that the long-term effect of warming on soil respiration rates in the Arctic could be larger than predicted based on short-term measurements of temperature sensitivity. Consequently, the substantial stores of carbon present in high-latitude soils may be even more vulnerable to climate warming than previously estimated. We also discuss the potential mechanisms underlying the observed patterns based on the extensive range of microbial assays carried out in this project.