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Microbial carbon dynamics along an elevational gradient in the central Austrian Alps

Victoria Martin (1), Shouquin Sun (1,2), Alberto Canarini (1), David Zezula (1), Marina Jecmenica (1), Martina Maczalová (1), Ivana Bogdanovic (1), Sarah Sidra (1), Gerd Dercon (3), Pascal Boeckx (4), Thomas Walker (5), and Andreas Richter (1)

(1) Department of Microbiology and Ecosystem Science, University of Vienna, Austria, (2) Institute of Mountain Hazards and Environment, Chinese Academy of Science, (3) Soil and Water Management & Crop Nutrition Laboratory, Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Austria , (4) Isotope Bioscience Laboratory (ISOFYS), Department of Green Chemistry and Technology, Ghent University, Coupure Links 653, 9000 Gent, Belgium, (5) of Ecology and Evolution, Université de Lausanne, Switzerland

Global warming is faster and more severe in alpine and arctic ecosystems than in most of the rest of the world. Additionally, these cold ecosystems are especially sensitive to warming and their soils store a significant amount of organic carbon (C) (more than twice the amount present in today's atmosphere). A thorough understanding of warming effects on microbial decomposition and processing of soil organic matter is therefore a prerequisite for modeling soil C feedbacks to the climate system. Elevation gradients represent directional changes in temperature and are a proxy for studying temperature effects on soil microbial C cycling. Most studies to date, however, focus on C stocks and CO_2 fluxes, and do not explicitly target microbial responses to climate change.

Our aim was to evaluate elevation effects on soil C dynamics and to elucidate links between microbial physiology (growth and turnover, C uptake, respiration and C use efficiency - CUE) and the susceptibility of soil organic matter to warming. We incubated soils from four ecosystem types along an elevation gradient in the central Austrian Alps for eleven weeks at 10 °C and 20 °C. We measured heterotrophic respiration at weekly intervals and estimated microbial growth and turnover, as well as microbial CUE, using a novel approach involving the incorporation of 18O from labeled water into microbial DNA. We also took accompanying measurements of soil nitrogen (N) and phosphorus (P) pools.

We found that soils at higher elevation sites, i.e. lower mean temperature, were characterized by higher molar C/N ratios, specific respiration rates over 24 hours and δ13C values of dissolved organic carbon. However, cumulative respiration expressed per g C, CUE, microbial growth and turnover time remained unchanged between different elevation sites. Laboratory warming increased cumulative respiration, with the strongest effects on the highest elevation soil. Warming also increased microbial growth and decreased microbial turnover time and CUE, but only in the lowest elevation soil. The temperature sensitivity (indicated by Q10 values) of cumulative respiration and growth were thus inversely affected by elevation change. Soil N and P dynamics most likely reflected differences in land use intensity along the gradient. We found a decrease in nitrate and an increase in ammonia and total free amino acid concentrations with increasing elevation, suggesting a more conservative N cycle at higher elevation. At the same time, the highest elevation site possessed the highest concentrations of total dissolved phosphorus, inorganic and organic phosphorus and the lowest concentrations of total phosphate.

Together, our results suggest that microbial respiration and CUE are unaffected by the elevation gradient, potentially representing a long-term thermal adaption in the soil microbial community. However, short-term warming of the same soils caused changes in microbial activity, thereby supporting previous studies that have reported temporary warming effects on excess C loss from soil.