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The influence of short-term and long-term warming on physical soil carbon pools

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Soils store more carbon than the atmosphere and total land plant biomass combined. Soil organic matter (SOM) can be classified into different physical pools characterized by their degree of protection and turnover rates. Usually, these pools are isolated by dividing soils in different water-stable aggregate size classes and, inside these classes, SOM fractions with differing densities and properties: Stable mineral-associated organic matter (MOM) and labile particulate organic matter (POM). Increasing temperatures are known to initially enhance microbial decomposition rates, releasing C from soils which could further accelerate climate change. The magnitude of this feedback depends on which C pool is affected the most by increased decomposition. Since MOM, thought to be the best protected carbon pool, holds most of the soil C, losses from this pool would potentially have the biggest impact on global climate. Experimental results are inconclusive so far, as most studies are based on short-term field warming (years rather than decades), leaving the ecosystem response to decades to century of warming uncertain.

We made use of a geothermal warming platform in Iceland (ForHot; https://forhot.is/) to compare the effect of short-term (STW, 5-8 years) and long-term (LTW, more than 50 years) warming on soil organic carbon and nitrogen (SOC, SON) and its carbon and nitrogen isotope composition ($\delta^{13}C$ and $\delta^{15}N$) in soil aggregates of different sizes in a subarctic grassland. OM fractions were isolated via density fractionation and ultrasonication both in macro- and microaggregates: Inter-aggregate free POM (fPOM), POM occluded within aggregates (iPOM) and MOM.

MOM, containing most of the SOC and SON, showed a similar response to warming for both macro- and microaggregates. Compared to LTW plots, STW plots overall had higher C and N stocks. But warming reduced the carbon content more strongly in STW plot than in LTW plots. $\delta^{13}C$ of MOM soil increased with temperature on the STW sites, indicating higher overall SOM turnover rates at higher temperatures, in line with the higher SOC losses. For LTW, $\delta^{13}C$ decreased with warming except for the most extreme treatment (+16°C). Warming duration had no impact on iPOM-C. fPOM-C decreased in STW sites with increasing temperature, while it increased on the LTW sites.

Overall our results demonstrate warming-induced C losses from the MOM-C-pool, thought to be most stable soil carbon pool. Thus, warming stimulated microbes to decompose both labile fPOM and more stable MOM. After decades of warming, C losses are less pronounced compared to the short-term warmed plots, pointing to a replenishment of the carbon pools at higher temperatures in the long-term. This might be explained by adaptations of the primary productivity and/or substrate-limitation of microbial growth.