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Quantitative and qualitative responses of soil organic carbon to six years of extreme soil warming in a subarctic grassland in Iceland

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Terrestrial carbon cycle feedbacks to global warming are expected, but constitute a major uncertainty in climate models. Soils in northern latitudes store a large proportion of the total global biosphere carbon stock and might thus become a strong source of CO_2 when warmed. Long-term in situ observations of warming effects on soil organic carbon (SOC) dynamics are indispensable for an in depth understanding of the involved processes. We investigated the effect of six years of soil warming on SOC quantity and quality in a geothermally heated grassland soil in Iceland. We isolated five fractions of SOC along an extreme soil warming gradient of +0 to +40°C. Those fractions vary conceptually in turnover time from active to passive in the following order: particulate organic matter (POM), dissolved organic carbon (DOC), SOC in sand and stable aggregates (SA), SOC in silt and clay (SC-rSOC) and resistant SOC (rSOC). Soil warming of 1°C increased bulk SOC by 22% (0-10 cm) and 27% (20-30 cm), while further warming led to exponential SOC depletion of up to 79% (0-10 cm) and 74% (20-30) in the most heated plots (∼ +40°C). Only the SA fraction was more sensitive than the bulk soil, with 93% (0-10 cm) and 86% (20-30 cm) losses and with the highest relative enrichment in 13C (+1.6‰ in 0-10 cm and +1.3‰ in 20-30 cm). In addition, the mass of the SA fraction did significantly decline along the warming gradient, which we explained by devitalization of aggregate binding mechanisms. As a consequence, the fine SC fraction mass increased with warming which explained the relative enrichment of presumably more slow-cycling SOC (R2=0.61 in 0-10 cm and R2=0.92 in 20-30 cm). Unexpectedly, no difference was observed between the responses of SC-rSOC (slow-cycling) and rSOC (passive) to warming. Furthermore, the 13C enrichment by trophic fractionation in the passive rSOC fraction was equal to this in the bulk soil. We therefore conclude that the sensitivity of SOC to warming was not a function of age or chemical recalcitrance, but rather triggered by changes in bio-physical stabilization mechanisms, such as aggregation.