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An isotopic investigation of the temperature response of young and old soil organic matter respiration

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The effect of temperature on rates of soil respiration is critical to our understanding of the terrestrial carbon cycle and potential feedbacks to climate change. The relative temperature sensitivity of labile and recalcitrant soil organic matter (SOM) is still controversial; different studies have produced contrasting results, indicating limited understanding of the underlying relationships between stabilisation processes and temperature. Current global carbon cycle models still rely on the assumption that SOM pools with different decay rates have the same temperature response, yet small differences in temperature response between pools could lead to very different climate feedbacks.

This study examined the temperature response of soil respiration and the age of soil carbon respired from radiocarbon dated fractions of SOM (free, intra-aggregate and mineral-bound) and whole soils (organic and mineral layers). Samples were collected from a peaty gley soil from Harwood Forest, Northumberland, UK.

SOM fractions were isolated from organic layer (5 - 17 cm) material using high density flotation and ultrasonic disaggregation - designated as free (< 1.8 g cm^{-3}), intra-aggregate (< 1.8 g cm^{-3} within aggregates > 1.8 g cm^{-3}) and mineral-bound (> 1.8 g cm^{-3}) SOM. Fractions were analysed for chemical composition (FTIR, CHN analysis, ICP-OES), ^{14}C (AMS), δ^{13}C and δ^{15}N (MS) and thermal properties (DSC).

SOM fractions and bulk soil from the organic layer and the mineral layer (20 – 30 cm) were incubated in sealed vessels at 30 ˚C and 10 ˚C for 3 or 9 months to allow accumulation of CO_2 sufficient for sampling. Accumulated respired CO_2 samples were collected on zeolite molecular sieve cartridges and used for AMS radiocarbon dating. In parallel, material from the same fractions and layers were incubated at 10 ˚C, 15 ˚C, 25 ˚C and 30 ˚C for 6 months and sampled weekly for CO_2 flux measurements using GC chromatography.

Initial data have shown radiocarbon ages ranging from modern to 219 y BP in bulk soil from the organic layer (5 – 17 cm depth), while free OM ranged from modern to 74 y BP, intra-aggregate OM 413 – 657 y BP and mineral-bound material 562 - 646 y BP. Bulk soil from the mineral layer (20 – 30 cm) was considerably older, at 2142 – 2216 y BP. These results indicate that within the upper layer of soil, mineral-bound OM represents a slow-cycling or recalcitrant pool of SOM; intra-aggregate OM is slightly less recalcitrant than mineral-bound OM, while free OM represents a fast-cycling, labile pool of SOM. Bulk soil from the mineral layer (20 – 30 cm) is much older than mineral-bound OM in the upper layers, suggesting the involvement of other stabilising factors associated with depth besides mineral interactions. The link between age and recalcitrance is corroborated by measured CO_2 flux rates, which increase with decreasing age of fractions.

Results for the ^{14}C contents and calculated ages of isolated SOM fractions, bulk organic and mineral soils and their respired CO_2 at different temperatures will be discussed and compared with long term trends in soil/SOM fraction CO_2 fluxes and their temperature sensitivity. Data on soil chemical characteristics and δ^{13}C values will also be presented.