Geophysical Research Abstracts
Vol. 21, EGU2019-14000, 2019
EGU General Assembly 2019

Element patterns and carbon turnover in soil microaggregates

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The mean residence time of organic matter in soil ranges from days to millenia. Although chemical and physical processes are known to control the storage of organic matter in soil, the role of spatial arrangements in soil remains largely unknown due to the lack of in-situ techniques operating on the micro-scale.

We asked whether deterministic patterns in element arrangement occur in large and small soil microaggregates (250-53 and 53-20 μm), and how these contribute to the storage of organic matter. To do so, we studied surface soils with increasing clay contents (sandy to loamy Luvisols, Germany) and subjected 60 individual aggregates to elemental mapping by electron probe micro analysis (EPMA), which recorded C, N, P, Al, Fe, Ca, K, Cl, and Si contents at micrometer scale resolution. We further developed the first laser-ablation isotope ratio mass spectrometry technique in soil science detecting d13C composition on the micro-scale (LA-IRMS) and employed this to trace micro-gradients in undisturbed soil and soil microaggregate samples.

We found a pronounced heterogeneity in aggregate structure and composition, which was not reproducible for different microaggregates from the same soil fraction, and which was largely independent from clay content in soil. However, neighborhood analyses revealed close spatial correlations between organic matter debris (C:N app. 100:10) and microbial organic matter (C:N app. 10:1), indicating a spatial relationship between source and consumer. There was no systematic relationship between soil minerals and organic matter, suggesting that well-established macroscale correlations between pedogenic oxides and clay with soil organic matter storage do not apply to soil microaggregates.

From first applications of LA-IRMS to soil we found also a high d13C variability of up to 9 per mill along spatial gradients of less than 300 μm, suggesting the appearance of very small hotspots of isotope enrichment and organic matter turnover by metabolic processes.