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Linking progressive SOC depletion to degradation of soil structure: Where does it fail first?

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Soil organic carbon (SOC) depletion is often a result of human land use, which is intensified by climate change. As SOC is closely linked to the stabilization of soil structure, the loss of SOC in a soil may induce soil structure breakdown and turnover processes that are not yet well understood.

In order to study soil structure turnover with respect to OC loss, we designed an incubation experiment with soil microcosms that allowed OC loss by leaching and microbial respiration, while avoiding any mechanical disturbance.

We incubated intact soil cores of an arable Luvisol from Loess deposits in southeastern Germany for 300 days at constant water tension and 25 °C to promote microbial activity. During incubation, CO_2 release from the microcosms was monitored. A subset of the microcosms was sampled monthly to assess the effect of progressive OC depletion on the stability and architectural features of the soil structure.

The incubation resulted in a reduction of the initial OC (11.2 mg g^{-1}) by approx. 20% and a narrower C:N ratio, corresponding to a reduced OC coverage of the mineral surfaces (1.7 m^2 g^{-1} to 0.9 m^2 g^{-1}, as determined by N_2-BET). Despite the OC reduction, the aggregate size distribution (as determined by both wet and dry sieving) did not change significantly, although there was a trend toward a reduction in the mean weight diameter of the aggregates. The mechanical stability of isolated soil aggregates (as determined by dry crushing) even increased slightly with lower OC content in the bulk soil. Microscopic analysis of resin-embedded soil aggregates revealed a lower bulk density in the center, suggesting a progressive carbon depletion from the outside to the inside of the soil aggregates.

These observations highlight that early stage OC depletion along with reduction of OC-covered mineral surface area, without additional mechanical influence, does not immediately lead to the degradation of soil structure. This suggests the existence of OC storage sites that are not

susceptible to OC loss by leaching or microbial degradation. In contrast, the sites of initial OC loss may not contribute to the structural stability of a soil.