Goldschmidt 2022 Abstract
https://doi.org/10.46427/gold2022.10983

Disentangling the interplay of soil organic carbon storage and structure dynamics through explicit spatial modeling at the pore scale

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The structure of soil aggregates plays an important role for the turnover of particulate organic matter (POM) and vice versa. Analytical approaches usually do not disentangle the continuous re-organization of soil aggregates, caught between disintegration and assemblage. This led to a lack of understanding of the mechanistic relationship between aggregation and OM dynamics in soils.

In this study, we took advantage of a process-based mechanistic model that describes the interaction between the dynamic (re-)arrangement of soil aggregates, based on dynamic image analysis data of wet-sieved aggregates, to analyze the turnover of POM, and simultaneous soil surface interactions in a spatially and temporally explicit way. Our novel modeling approach enabled us to unravel the temporal development of aggregate sizes, OC turnover of POM, and surface coverage as affected by soil texture, POM input and POM decomposition rate, affected e.g. by temperature, comparing a low and high clay soil (18 % and 33 % clay content).

Our results reveal the importance of the dynamic re-arrangement of soil structure on POM-related turnover of OC in soils. Firstly, aggregation was largely determined by the POM input fostering aggregates through additional gluing joints outweighing soil texture at lower decomposition rate whereas at higher decomposition rate, soil texture had a higher influence leading to larger aggregates in the high clay soil. Secondly, the POM storage increased with clay content, showing that surface interactions may delay the turnover of OC into CO2. Thirdly, we observed a structural priming effect in which the increased input of POM induced increased structural re-arrangement stimulating the mineralization of old POM. This work highlights that the dynamic re-arrangement of soil aggregates has important implications for OC turnover and is driven by underlying surface interactions where temporary gluing spots stabilize larger aggregates.

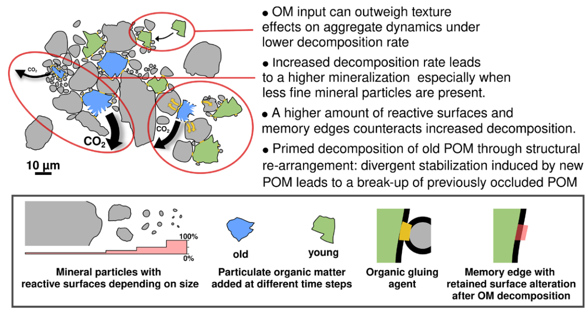

Figure 1: Graphical Abstract