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Drivers of the distribution of soil organic matter fractions along a geo-climatic gradient

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The concept of distinct soil organic matter (SOM) fractions – with differing formation pathways, stabilization mechanisms and responses to change – is a promising avenue to improve our understanding of soil carbon (C) dynamics. While there is widespread consensus on the general usefulness of conceptual fractions with specific functional implications, there is still a lack of information on the patterns with which they contribute to bulk soil organic carbon (SOC) stock at larger scales and across climatic and soil physicochemical gradients. In this study, we aimed to assess first the quantitative importance of three key SOM fractions across a diverse range of 12 soil groups with global significance. Secondly, we wanted to gain insights on the environmental drivers that shape the contribution of these fractions to SOC stocks.

Here we sampled a set of 35 grassland topsoils (0 – 10 cm) along a 3000 km north-south transect in Chile ranging from subpolar to Mediterranean climate, and covering 12 WRB major soil groups. Following a modified version of the protocol in Zimmermann et. al (2007), we partitioned the soils into three functional SOM fractions defined by particle size and density (free silt and clay, free particulate organic matter, stable microaggregates), enabling us to quantify SOC stocks and the relative contribution to SOC in these three fractions. In order to identify links between fractions and potential drivers of C stabilization, we further characterized extensively relevant physico-chemical properties of the soils, compiled climatic data of the sites and characterized OM maturity (DRIFT spectroscopy and Rock-Eval pyrolysis) as well as pedogenic, secondary Fe-, Al- and Mn-oxide concentrations through sequential extraction.

We found that the contributions of mineral-associated SOM fractions to bulk SOC varied strongly across the soil gradient, while the contribution of free particulate organic matter was comparatively stable and low. SOM associated with free silt and clay sized particles are the most important C reservoir in soils with less than 4 % SOC, whereas in soils with higher SOC content, the majority of the SOC is contained in stable microaggregates. The SOC stock in various fractions was sensitive to changes in temperature, pedogenic oxides, and OM input vs. decomposition. Comparison of OM maturity showed that free particulate OM and free silt and clay associated OM can be clearly distinguished, while OM in microaggregates is likely a mixture of both. However, drivers of OM composition in microaggregates could not be identified.

This study demonstrates that in SOC-rich soils, microaggregates represent a major fraction of bulk SOC, and that SOC stocks in key SOM fractions can be linked to distinct climatic and soil physicochemical factors.