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Improving estimates of maximal organic carbon stabilization by fine soil particles

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Abstract Organic carbon (C) associated with fine soil particles (<20 μm) is relatively stable and accounts for a large proportion of total soil organic C (SOC). The soil C saturation concept proposes a maximal amount of SOC that can be stabilized in the fine soil fraction, and the soil C saturation deficit (i.e., the difference between current SOC and the maximal amount) is presumed to affect the capacity, magnitude, and rate of SOC storage. In this study, we argue that predictions using current models underestimate maximal organic C stabilization of fine soil particles due to fundamental limitations of using least-squares linear regression. The objective was to improve predictions of maximal organic C stabilization by using two alternative approaches; one mechanistic, based on organic C loadings, and one statistical, based on boundary line analysis. We collected 342 data points on the organic C content of fine soil particles, fine particle mass proportions in bulk soil, dominant soil mineral types, and land use types from 32 studies. Predictions of maximal organic C stabilization using linear regression models are questionable because of the use of data from soils that may not be saturated in SOC and because of the nature of regression itself, resulting in a high proportion of presumed over-saturated samples. Predictions of maximal organic C stabilization using the organic C loading approach fit the data for soils dominated by 2:1 minerals well, but not soils dominated by 1:1 minerals; suggesting that the use of a single value for specific surface area, and therefore a single organic C loading, to represent a large dataset is problematic. In boundary line analysis, only data representing soils having reached the maximal amount (upper tenth percentile) were used. The boundary line analysis estimate of maximal organic C stabilization (78 ± 4 g C kg^{-1} fraction) was more than double the estimate by the linear regression approach (33 ± 1 g C kg^{-1} fraction). These results show that linear regression models do not adequately predict maximal organic C stabilization. Soil properties associated with soil mineralogy, such as specific surface area and organic C loading, should be incorporated to generate more mechanistic models for predicting soil C saturation, but in their absence, statistical models should represent the upper envelope rather than the average value.

Keywords Soil organic carbon · Soil carbon saturation · Boundary line analysis · Fine soil particles · Organic carbon loading

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