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Soil organic matter stability in organo-mineral complexes as a function of increasing C loading

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ABSTRACT

Soil carbon (C) saturation behavior predicts that soil C storage efficiency observed under field conditions decreases as a soil approaches C saturation. This may be due to a decline in soil organic matter (SOM) stability as the result of changes in the type, strength or turnover time of organo-mineral interactions with increasing organic C input. The goal of this study was to test whether the stability of organic matter bound to soil minerals decreases as organo-mineral complexes approach C saturation with increasing C loading. A series of batch sorption experiments with natural dissolved organic matter (DOM) and soil mineral components was conducted to obtain organo-mineral complexes with a range of organic C loadings. The relative stability of C in these organo-mineral complexes was subsequently assessed using evolved CO_2 gas analysis during thermal analyses and laboratory incubations. Results indicated that differences in dissolved organic C before and after sorption overestimated the amount of sorbed C when compared to differences in solid-phase C concentrations. Values of C/N, $\delta^{13}C$, and $\delta^{15}N$ of the organo-mineral complexes were significantly smaller or more negative than initial soil samples or the stock DOM solution, consistent with the concept of molecular fractionation by sorption to minerals and suggesting that the composition of the organic matter in the organo-mineral complexes may have changed as the amount of sorbed organic matter increased. Observations that organic C loadings at maximum sorption did not substantially exceed 1 mg C m^{-2} and linear rather than asymptotic relations between sorbed C and initial DOM concentrations suggest that organo-mineral complexes may not have reached C saturation under the conditions in the batch sorption experiments of this study. The temperature at which half of the CO_2 evolved during thermal analysis (i.e., CO_2-T_{50}) increased with increasing C loading, suggesting the sorbed C required greater energy input for combustion. Results of the laboratory incubations to determine relative biological stability of sorbed C were not consistent with the initial hypothesis. The size of potentially mineralizable C pool relative to the total sorbed C decreased with increasing C loading, even though this pool was being degraded more rapidly. Overall, the results did not support the hypothesis that SOM stability decreases with increasing C loading. In spite of generating a wide range of C loadings substantially greater than previous studies, the conditions of the DOM sorption experiments conducted in this study appeared unable to generate organo-mineral complexes exhibiting C saturation behavior. We speculate that measurable decreases in SOM stability may occur only once the threshold of C saturation is reached.

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1. Introduction

Most current models of soil organic matter (SOM) dynamics assume that soil organic carbon (C) stocks increase linearly with increasing organic C inputs without an upper limit (Paustian et al., 1997). In a few cases, however, soil C stocks have showed no significant increase in response to increasing long-term organic C inputs, reaching a maximal soil C level (Campbell et al., 1991; Gulde et al., 2008; Huggins et al., 1998; Soon, 1998). This phenomenon has been proposed as the soil C saturation concept (Six et al., 2002; Stewart et al., 2007; West and Six, 2007), and the maximal soil C stock has been defined as the soil C saturation level. Subsequent studies demonstrated that chemically protected organic matter bound to soil minerals as organo-mineral complexes are more likely to reach C saturation than other physical or chemical

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