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Influence of pore structure on carbon retention/loss in soil macro-aggregates

Michelle Quigley (1), Alexandra Kravchenko (1), and Mark Rivers (2)

(1) Plant, Soil and Microbial Science, Michigan State University, East Lansing,MI USA, (2) Department of Geophysical Sciences and Center for Advanced Radiation Sources, The University of Chicago, Argonne, IL USA

Carbon protection within soil macro-aggregates is an important component of soil carbon sequestration. Pores, as the transportation network for microorganisms, water, air and nutrients within macro-aggregates, are among the factors controlling carbon protection through restricting physical accessibility of carbon to microorganisms. The understanding of how the intra-aggregate pore structure relates to the degree of carbon physical protection, however, is currently lacking. This knowledge gap can lead to potentially inaccurate models and predictions of soil carbon's fate and storage in future changing climates. This study utilized the natural isotopic difference between C3 and C4 plants to trace the location of newly added carbon within macro-aggregates before and after decomposition and explored how location of this carbon relates to characteristics of intra-aggregate pores. To mimic the effect of decomposition, aggregates were incubated at 23°C for 28 days. Computed micro-tomographic images were used to determine pore characteristics at 6 μm resolution before and after incubation. Soil (0-10 cm depth) from a 20 year continuous corn (C4 plant) experiment was used. Two soil treatments were considered: 1) "destroyed-structure", where 1 mm sieved soil was used and 2) "intact-structure", where intact blocks of soil were used. Cereal rye (*Secale cereale* L.) (C3 plant) was grown in the planting boxes (2 intact, 3 destroyed, and one control) for three months in a greenhouse. From each box, $\sim$5 macro-aggregates of $\sim$5 mm size were collected for a total of 27 macro-aggregates. Half of the aggregates were cut into 5-11 sections, with relative positions of the sections within the aggregate recorded, and analyzed for δ^{13}C. The remaining aggregates were incubated and then subjected to cutting and δ^{13}C analysis. While there were no significant differences between the aggregate pore size distributions of the two treatments, the roles that specific pores sizes played in carbon protect were disparate. In intact-structure aggregates, prior to incubation, there was no association between carbon distribution and pores. After incubation, significant correlations (α=0.05) were observed between abundance of 6-40 μm pores and both soil organic carbon (SOC) and δ^{13}C. Sections containing more 6-40 μm pores also had increased amounts of SOC (r^2=0.23) with higher presence of C4 carbon (r^2=0.27). This indicates preferential preservation of older carbon in the pores of this size range. Prior to incubation, destroyed-structure aggregates had higher amounts of C3 carbon associated with 40-95 μm pores (r^2=0.14), pointing to a greater presence of newly added carbon within these pores. However, after incubation there was a significant loss of SOC from these pores (r^2=0.22) and, specifically, the loss of C3 carbon (r^2=0.16). In the studied soil, pores of 6-40 μm size range appeared to control the preservation of older carbon, while 40-95 μm pores controlled the fate of newly added carbon. Older carbon preservation in 6-40 μm pores was mostly observed in macro-aggregates from the soil with intact structure, while the associations between 40-95 μm pores and gains and losses of newly added carbon were primarily observed in the macro-aggregates that were formed anew in the sieved soil during the plant growing experiment.