Geophysical Research Abstracts
Vol. 16, EGU2014-16391, 2014
EGU General Assembly 2014

Relationship between chemical structure of soil organic matter and intra-aggregate pore structure: evidence from X-ray computed micro-tomography

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Understanding chemical structure of soil organic matter (SOM) and factors that affect it are vital for gaining understanding of mechanisms of C sequestration by soil. Physical protection of C by adsorption to mineral particles and physical disconnection between C sources and microbial decomposers is now regarded as the key component of soil C sequestration. Both of the processes are greatly influenced by micro-scale structure and distribution of soil pores. However, because SOM chemical structure is typically studied in disturbed (ground and sieved) soil samples the experimental evidence of the relationships between soil pore structure and chemical structure of SOM are still scarce. Our study takes advantage of the X-ray computed micro-tomography (μ-CT) tools that enable non-destructive analysis of pore structure in intact soil samples. The objective of this study is to examine the relationship between SOM chemical structure and pore-characteristics in intact soil macro-aggregates from two contrasting long-term land uses. The two studied land use treatments are a conventionally tilled corn-soybean-wheat rotation treatment and a native succession vegetation treatment removed from agricultural use >20 years ago. The study is located in southwest Michigan, USA, on sandy-loam Typic Hapludalfs. For this study we used soil macro-aggregates 4-6 mm in size collected at 0-15 cm depth. The aggregate size was selected so as both to enable high resolution of μ-CT and to provide sufficient amount of soil for C measurements. X-ray μ-CT scanning was conducted at APS Argonne at a scanning resolution of 14 μm. Two scanned aggregates (1 per treatment) were used in this preliminary study. Each aggregate was cut into 7 “geo-referenced” sections. Analyses of pore characteristics in each section were conducted using 3DMA and ImageJ image analysis tools. SOM chemistry was analyzed using pyrolysis/gas chromatography-mass spectroscopy. Results demonstrated that the relationships between SOM chemical structure and pore characteristics differed in the aggregates of the two treatments. For example, in the agricultural treatment, the aggregate sections with prevalence of small pores had lower relative lignin abundance, while higher lignin abundances occurred in aggregate sections with more large pores. This relationship could be reflecting the low accessibility of the sections dominated by small pores to plant roots. It is interesting to note that no relationship between pores and lignin were observed in the aggregate from the native succession treatment. In the native succession aggregate we found that a larger presence of protein and N-bearing compounds was associated with sections with greater presence of 35-90 μm pores. This could be a result of fungal activities, as pores of this size constitute a primary fungal habitat and fungi are known for secreting proteins. Fewer fungi in the soil under agricultural management are likely the reason that no such relationship was observed in the aggregate from the agricultural treatment. Our preliminary results indicate that substantial spatial variability patterns in SOM chemical structure can exist even within a single macro-aggregate and that pores are likely a main driver of intra-aggregate SOM chemistry.