Dependence of Sorption of Dissolved Organic Carbon On Soil Order Classification

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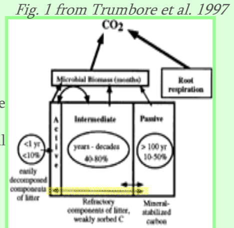
Motivation

Soil carbon is the largest terrestrial sink. The top meter of soils contain about several times the mass of carbon in standing biomass. DOC (dissolved organic carbon) is the most mobile fraction of soil carbon. We are interested in the mechanisms and properties that dictate how DOC is sorbed and stabilized onto mineral soils, transforming it to a passive pool of C (*Figure 1).*

Fig. 1 from Trumbore et al. 1997



Many mineral soils are not saturated with DOC (Jardine et al. 1989). Certain anthropogenically altered soils have demonstrated the ability to sustain large quantities of soil organic carbon in mineral soils (*Figure 2*). The objective of this project is to quantify the relationship between dissolved organic carbon sorption capacity and physical and geochemical properties of subsoils.

Fig. 2 from Sombroek et al. 1993

Methods

Soil Selection:

An area-weighted sampling of series in the US with coverage to the great group level in the eastern US (*Figure 3*). B and C horizons were obtained from the Natural Resource Conservation Service (NRCS). 250 samples have been analyzed from 73 series and 5 orders.

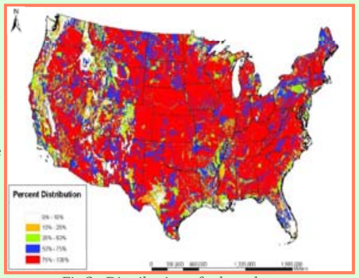


Fig 3: Distribution of selected representative soils at the great group level

Analysis of Samples

Soil samples were oven-dried, ground, and sieved in the standard manner. The following properties were analyzed in all samples: pH in water and $CaCl_2$, total organic and inorganic carbon, iron oxide content, and particle size analysis.

DOC Sorption Capacity

Sorption isotherms were conducted using a natural DOC source (0-100 ppm) with a solid solution ration of 1:60 over 48 h. Blanks were used to determine the maximum additional DOC sorbed by optimizing a Langmuir equation (*Eq 1*), and overall maximum DOC sorption capacity was found by subtracting the amount of desorption (Kothawala et al., 2009) (*Figure 4*).

$$RE = \frac{k\, Q_{max}\, X_f}{1 + k\, X_f} - b$$

Equation 1: Langmuir isotherm, where RE is amount of DOC sorbed or desorbed in mg/kg, X_f is the final equilibrium concentration of DOC in pm, k is binding affinity, Q_{max} is maximum adsorption capacity (in mg/kg), and b, the desorption potential in mg/kg, was found experimentally.

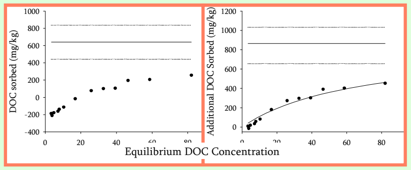


Fig 4: Example of isotherm fitting. Left is raw data, right with blank subtraction and Langmuir fit. Solid lines represent maximums modeled, with standard errors

Results

The average sorption capacities for the soils were similar*(Figure 5*). These three orders of soils dominate the eastern US.

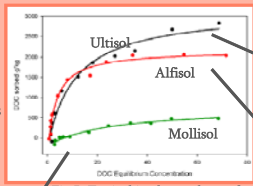


Fig 5. Typical isotherm shapes for three major soil orders

Ultisols

Fig 7a: Typical Ultisol profile*

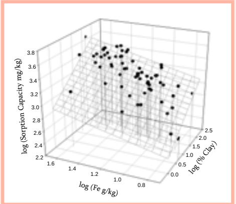


Fig 7c : Observed and model fitted data , where log Qmax = 2.141 + 0.403log (%clay) + 0.439log (Fe)

Fig 7b(above): Distribution of Ultisols*

Ultisols dominate the Southeast US (*Figure 7b)* with deep, acidic profiles rich in clay and iron content (*Figure 7a).* DOC sorption onto subsurface Ultisols can be predicted by textural clay content and iron content (r^2 = 0.554, *Figure 6b).* These results suggest that both ligand exchange are important mechanisms for DOC sorption onto Ultisols.

Mollisols

Fig 6a: Typical Mollisol profile*

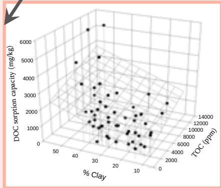


*Fig 6b: Observed and model fitted data, where Qmax = -206.452 + 0.127*TOC) - 46.880*%clay)*

Fig 6c: Distribution of Mollisols*

Mollisols dominate the Great Plains (Figure 6c) with deep, often basic profiles rich in organic carbon (Figure 6a). DOC sorption onto subsurface Mollisols can be predicted by clay and TOC (r^2 = 0.321, Figure 6b), suggesting that organic-organic interactions was important for DOC sorption.

Alfisols

Fig 8a: Typical Alfisol profile*

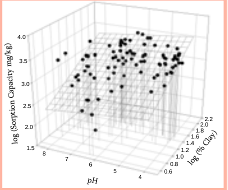


Fig 8b (above): Observed and model fitted data , where: Log Qmax = 2.662 + 0.572 log (%clay) – 0.0602 log (pH)

Alfisols dominate the land around the Great Lakes and Mississippi River (*Figure 8c)* with deep, clayey profiles rich in iron and aluminum (*Figure 8a).* DOC sorption onto subsurface Alfisols can be predicted by textural clay content and pH (r^2 = 0.251, *Figure 6b).* These results suggest that ion exchange is an important mechanism for DOC sorption onto Alfisols.

Fig 8c: Distribution of Alfisols*

** Figures of soil order distribution and profiles from the NRCS*

Evidence for Preferential Sorption

Overall, a trend in different isotherm shapes has implications in preferential sorption. Although it has been shown that soils sorb DOC with respect to DOC structure, it seems as if Mollisols and Ultisols have very different preferential sorption.

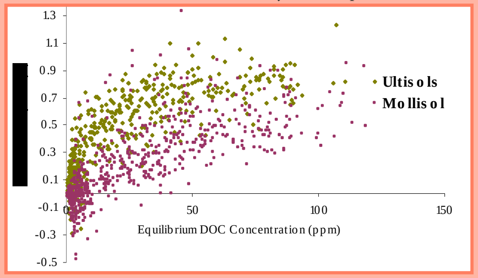


Figure 9: Equilibrium DOC concentration vs Extent of Sorption (defined as DOC sorbed/modeled DOC sorption capacity).

Conclusions

The empirical equations here can be used to some extent to predict DOC sorption capacity on subsoil chemical and physical properties.

This predictive power can now be coupled with readily available databases (ie: NRCS) for subsurface DOC sorption potential with minimal effort.

Although other literature has shown that soils preferentially adsorb DOC based on its chemical structure, our data show that this preferential sorption is different between soil orders, most notably Mollisols and Ulitsols.

Further Studies

A spatial representation of the "hot spots" for subsurface carbon sequestration will identify regions and field sites that exhibit greatest potential for enhanced subsurface organic carbon storage and thus most deserving of manipulation or improved management.

More experiments are needed to understand how differences in the organic C-mineral structure contribute to the observed preferential sorption differences between Mollisols and Ultisols.

Acknowledgements

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