Impact of Mineral Weathering and Organic Matter on Soil Water Retention

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Abstract

Water retention of soils and rock in the unsaturated zone is important for predicting flow and solute transport through the subsurface and likely affects mineral weathering. We are evaluating the effects of 1) weathering and 2) organic matter on soil water retention. A WP4C Dewpoint Potentiameter (Decagon Devices, Inc., Pullman, WA) is used to measure the water retention behavior of soil and sapprolite samples from ground surface to 100 cm depth at Laurel Preserve in West Chester, PA. The data from the WP4C are used to derive the -1.5 MPa to -300 MPa section of the water retention curve. We hypothesize that soil from shallower depths will retain more water than soil from deeper depths due to higher surface area resulting from a greater extent of weathering near the surface compared to sapprolite at deeper depth. Specific surface area (SSA) can be predicted by regression analysis using water retention curves. Samples are separated into two identical sets from the same depths, and organic matter removal pretreatment is used for one set. This is done to observe whether the presence of organic matter in soils reduces the SSA for mineral weathering to occur and therefore the ability of samples to retain water. We hypothesize that the organic matter removal treatment could reduce the water adsorption ability to certain degrees, especially for shallow depths which contain high organic matter content.

Hypotheses & Methods

Hypothesis

- Soil from shallow depths will retain more water than soil from deeper depths since it has been weathered to a higher degree and has more exposed specific surface area.
- The impact of organic matter (OM) on the water adsorption capacity differs depending on organic matter content.
  - Soil with high OM content could adsorb more moisture thus increasing the water adsorption capacity.
  - In soils with low OM content, the OM occupies the mineral surface area, therefore decreasing water adsorption capacity.

Methods

- Data Collection: WP4C used to measure water potential in samples

Soil Samples

Analyzing samples in the lab

WP4C, accurate measurement range: -1.5 - ~ -300 MPa

Theory

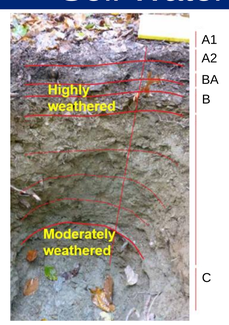
- Regression Analysis: Tuller and Or (TO) Regression Model

$$\Psi = \frac{\rho_w * Asvl}{6\pi g} * \frac{Sa^3}{\theta_m^{\ 3}}$$

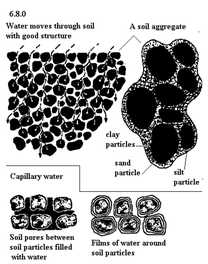
WP4C measures Ψ, from that we can calculate θ_m. Since $\frac{\rho_w * Asvl}{6\pi g}$ is a constant we can then solve for Sa for different depths using the TO regression model.

Ψ	Matric Potential of soil
ρ_w	Density of water 1000 kg/m^2
A_{svl}	Hamaker constant (-6 x 10^{-20} J)
g (m/s^2)	Gravity constant 9.8 m/s^2
Sa (m^2/g)	Surface area
θ_m (g/g)	Gravimetric water content (function of Sa)
h (m)	Thickness of water film present on soil grain (Used to derive equation)

Soil Water Retention



Soil horizon profile from our sampling site



Groundwater movement in the unsaturated zone and how soil grains adsorb water

http://www.uq.edu.au/_School_Science_Lessons/Soils.html

Results 1: OM Present

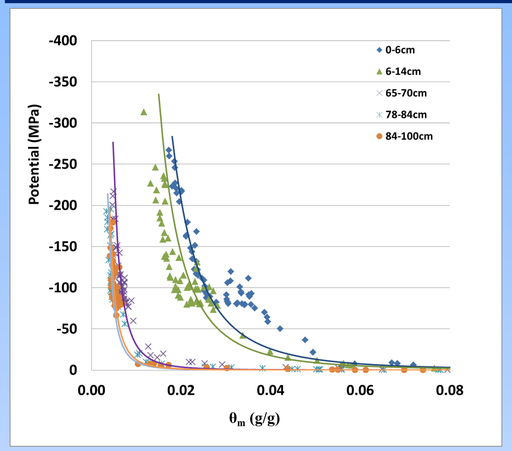


Table 1 Depths & estimated surface area

Depth (cm)	Soil Horizon	Estimated SSA(m^2/g)	R^2
0-6	A	80	0.89
6-14	A	70	0.83
65-70	B	20	0.84
78-84	B	15	0.84
84-100	C	16	0.82

Figure 1 (left): Water content (θ_m) vs. Matric Potential (MPa)

- As depth increases from 0 to 100 cm, the weathering degree decreases, therefore the soils generally retain less water.
- SSA decreases with depth as shown by the TO regression analysis results.
- SSA ranges from 15 to 80 m^2/g.

Results 2: OM Removed

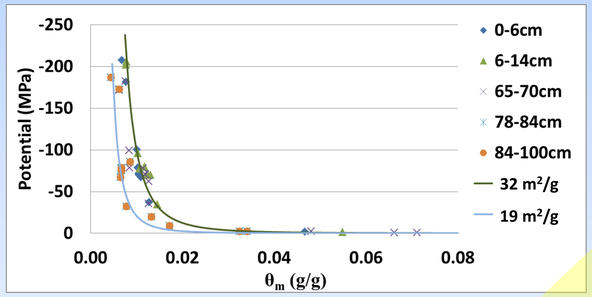


Figure 2 (left): Water content (θ_m) vs. Matric Potential (MPa)

- The SSA estimations with OM removed now range from 19 to 32 m^2/g.

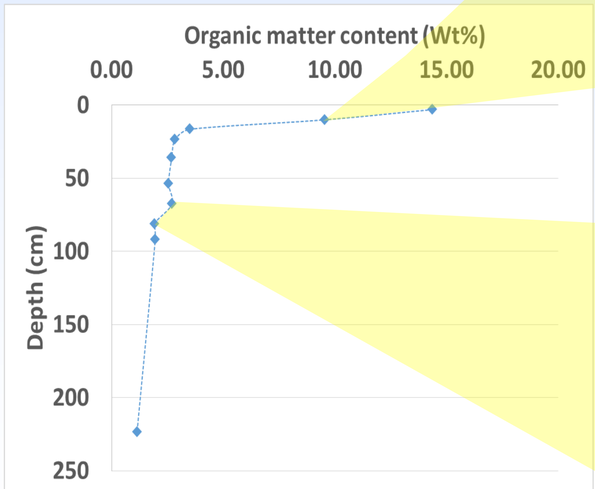


Figure 3 (above): Organic matter content (Wt%) vs. Depth (cm)

- As depth increases OM content decreases.

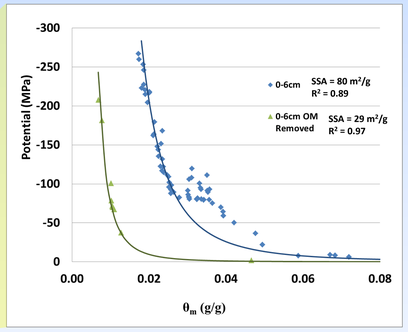


Figure 4 (above): Water content (θ_m) vs. Matric Potential (MPa)

- As organic matter content decreases water retention properties decreases.
- Estimated SSA decreases by over half in the OM removed samples (80 m^2/g to 29 m^2/g).

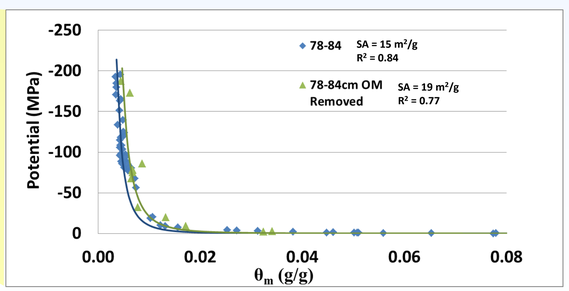


Figure 5 (above): Water content (θ_m) vs. Matric Potential (MPa)

- Specific surface area increases at this deeper depth when OM is removed (15 m2/g to 19 m2/g). This is due to the fact that OM occupies SSA.

Estimated SSA

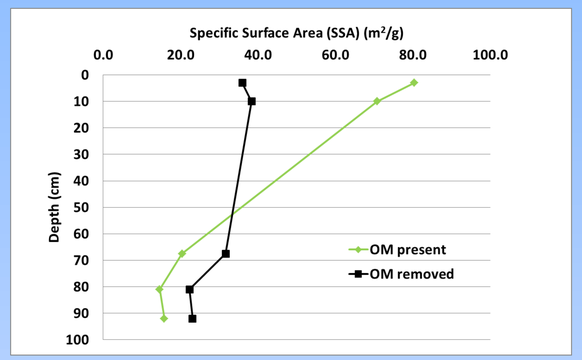


Figure 6: SSA (m^2/g) vs. Depth (cm) with varying weathering degrees and organic matter content.

- In both OM present and OM removed SSA generally decreases with depth.
- Organic matter removal in high organic matter content zones (shallower depths) could generally decrease the estimated SSA. Excessive OM that is not complexed at the mineral's surface contributes to Bulk SSA.
- Organic matter removal in low organic matter content zones (deeper depths) could potentially increase the estimated SSA.

Conclusion

- Shallower, more weathered soil retains more water than deeper, less weathered soil.
- Water retention properties at shallower depths are significantly affected by organic matter removal. From figure 4 (0-6 cm depth) it is shown that water retention is decreased after OM removal treatment, and estimated SSA is reduced by half compared to OM present. Deeper depths are not as affected by OM removal treatment as shallower depths even though there is a slight increase in water retention due to OM removal in figure 5 (78-84 cm depth).

References

- Saxon, K.E., Rawls, W.J., (2006). Soil water characteristic estimates by texture and organic matter for hydrologic solutions. *Soil Science Society of America Journal 70*, 1569–1578.
- Tuller, M., & Or, D. (2005). Water films and scaling of soil characteristic curves at low water contents. *Water Resources Research*, *41*(9).

Acknowledgements

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