Characterization of Soil Structure and Pore Architecture from the Aggregate to Horizon Scale

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Introduction

1. While many studies have examined the fractal structure of small aggregates, very few have characterized the mass-volume relationship of large aggregates and peds.

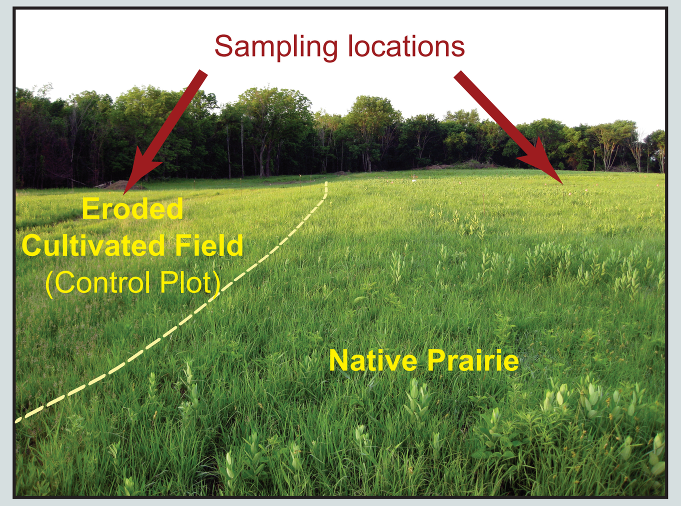
This relationship can be expressed as: $M(d) = k_m d^{D_m}$

where, $M(d)$ = aggregate mass of diameter d
k_m = aggregate mass of unit diameter
D_m = fractal dimension of mass

and, L = lacunarity = $var[(k_m)_i]$

$$(k_m)_i = \frac{M(d_i)}{d_i^{D_m}}$$

2. By applying multistripe laser triangulation (MLT) technology, we sought to characterize the fractal mass-volume relationship of aggregates and large peds over a wider range of scales than has been previously possible. Additionally, we examined the application of this technology to examine horizon-scale pore architecture.



We sampled two plots representing an unplowed Native Prairie and an adjacent cultivated field that has been eroded ~20-50 cm since the beginning of the last century.

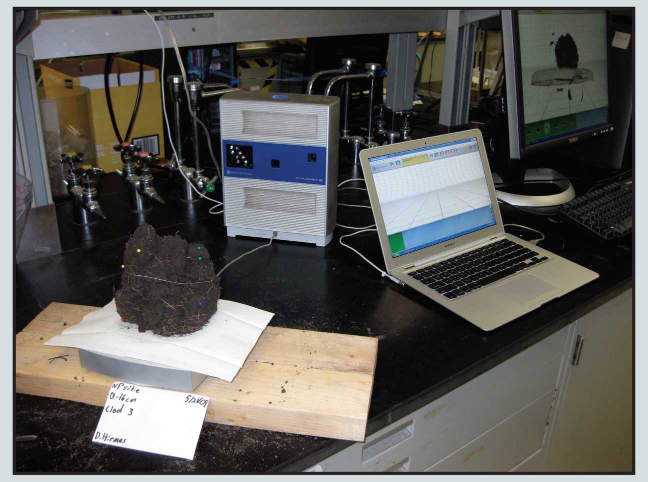
Both the surface and the Btss1 horizon was sampled from each field.

Methods

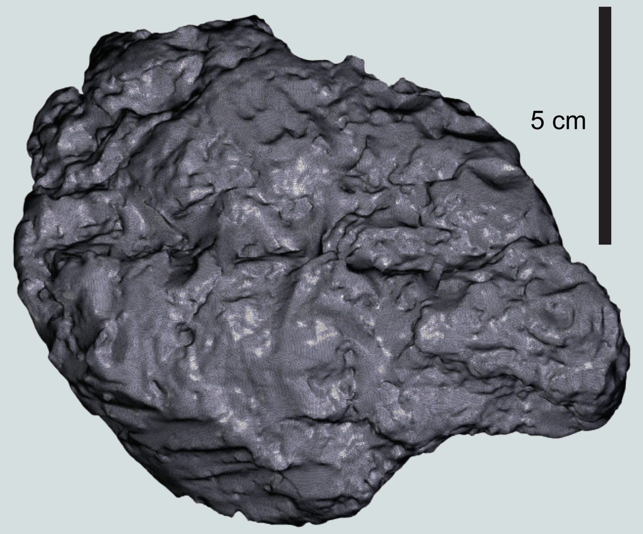
3. Six large (500 - 1000 cm³) aggregates/clods were collected from a hand-excavated pit at each sampling location.

4. Volumes of large clods were measured with a MLT scanner and broken into smaller aggregates.

MLT scanner and large clod



Resulting digital model

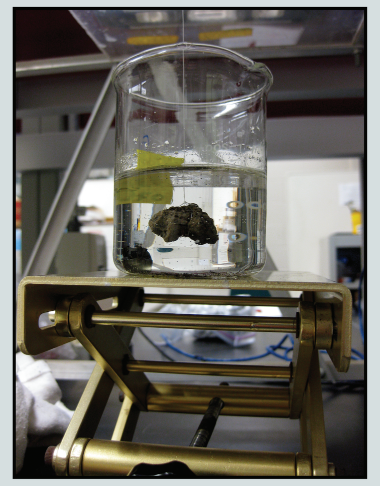


5. These aggregates were likewise measured for volume by either MLT scanning on larger aggregates or saturation in a glycerine/water mixture and displacement in kerosene on smaller aggregates.

A total of 18 large aggregates and approximately 120 small aggregates per horizon were measured.

Small aggregates saturated in glycerine/water

Displacement in kerosene



6. Aggregate diameter was determined by taking the cubic root of the measured volume and normalizing by shape.

We used roundness, R, as the shape parameter: $R = \frac{4A}{\pi\sqrt{d_l}}$

where, A = cross-sectional area
d_l = longest diameter in the cross section

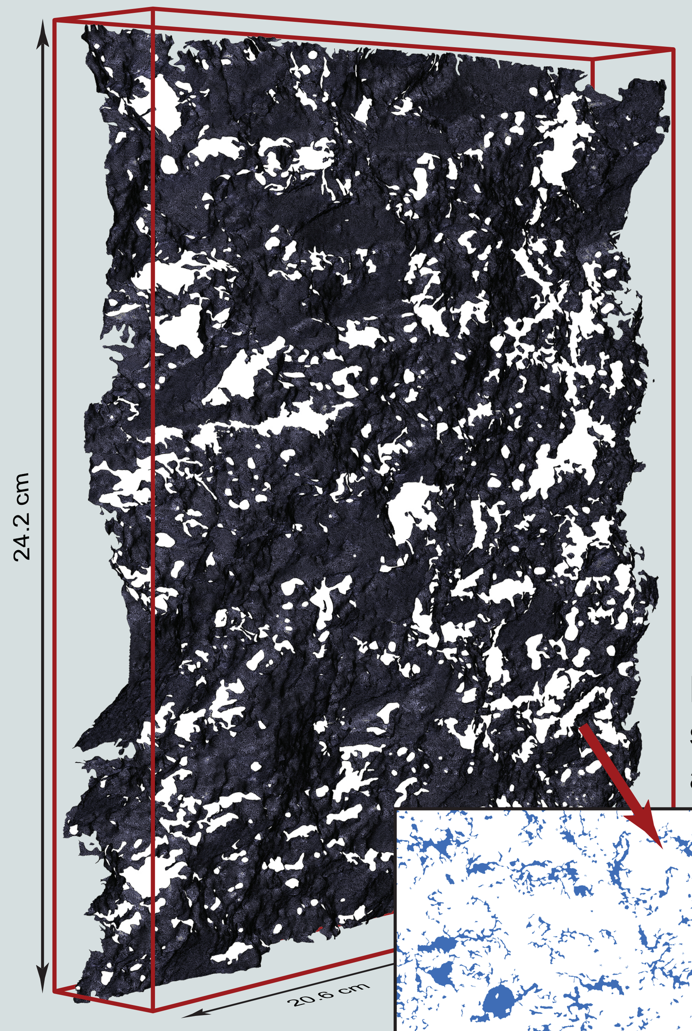
Normalized diameter, d_n, was calculated as: $d_n = \sqrt[3]{V}\sqrt{R}$

where, V = measured volume

We used ImageJ software to calculate R and d_n from photos of small aggregates and digital cross-sections of large aggregates.

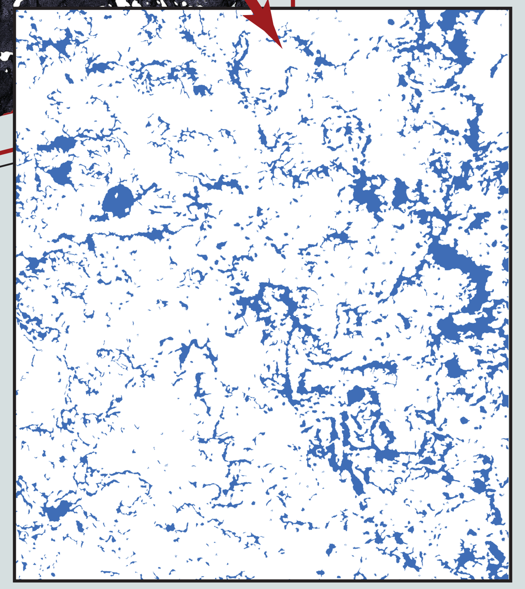
7. Pore architecture was assessed using data from MLT scans of the two excavation walls.

Results



Digital scan of the Control Plot Btss1 horizon

Pores are selected and measured



8. Linear regression analyses show that the mass-volume relationships are fractal with the exception of the Btss1 horizon from the Native Prairie soil.

Regressions were run on the linearized model: $\log M = \log k_m + D_m \log d$

9. Piecewise regression confirmed that the MLT scans accurately extended the range of aggregate volumes.

Breakpoints for the piecewise regression did not consistently occur at the break between the two methods used suggesting that both methods accurately measure volumes at different sizes.

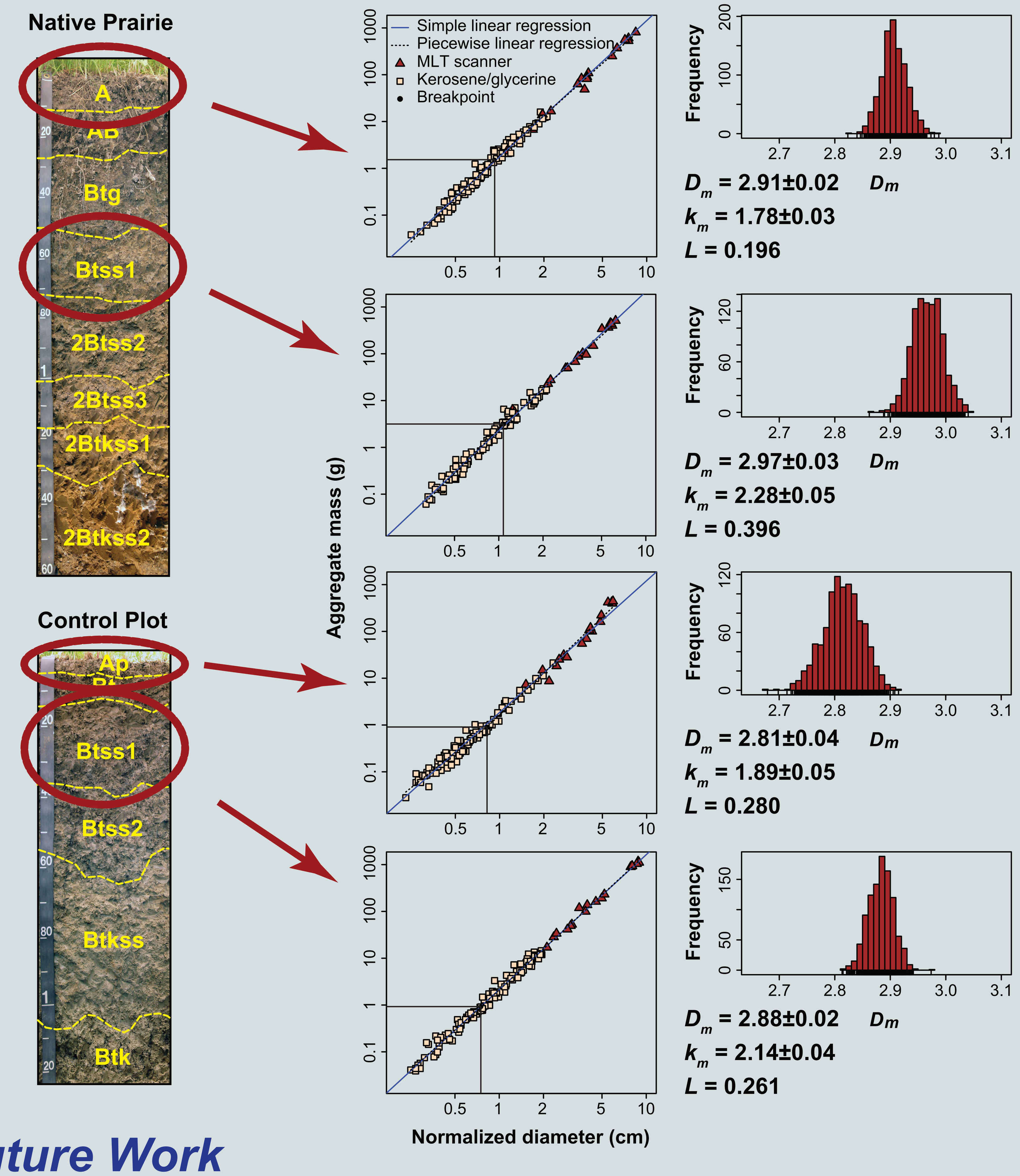
10. Holes in the digital scans of excavation walls were used as a proxy for soil pores and statistics calculated.

Horizon	Mean Pore Area (mm²)	Mean Pore Perimeter (mm)	Mean Pore Thickness (mm)	Organic Carbon (%)	Bulk Density (g cm⁻³)
Native Prairie					
A	38.1±374	41.6±322	0.50±6.6	2.95	1.14±0.04
Btss1	10.8±56	22.4±78	0.60±5.8	0.51	1.38±0.04
Control Plot					
Ap	6.1±29	25.7±86	0.32±5.3	4.27	1.01±0.03
Btss1	6.4±33	18.8±53	0.44±4.7	0.64	1.41±0.07

11. Soil properties, fractal model parameters, and mean pore measurements were related using a correlation matrix.

Correlation Matrix

	Area	Per.	Thi.	OC	BD	D_m	k_m	L
Area	1							
Per.	**0.95**	1						
Thi.	0.32	0.08	1					
OC	0.23	0.52	-0.72	1				
BD	-0.26	-0.55	0.66	**-1.00**	1			
D_m	0.30	0.05	**1.00**	-0.74	0.68	1		
k_m	-0.62	**-0.80**	0.53	**-0.86**	**0.84**	0.55	1	
L	-0.59	-0.64	0.45	-0.50	0.45	0.47	**0.84**	1



Summary and Future Work

12. We found a fractal mass-volume relationship throughout the wide range of aggregate sizes used in this study (0.05 - 1000 g) and a strong correlation between fractal dimension and pore thickness.

13. While MLT scanning shows enormous promise in quantitatively describing soil architecture, particularly for aggregate/ped structure and pore morphology, the next step is to relate these descriptions to pedogenic processes, water flux, and land-use.

Acknowledgements

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