# Fractal characterization of the intra-aggregate pore heterogeneity in macro-aggregates from contrasting land use and management treatments

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## Introduction

Soil aggregates play an important role in many soil processes, including solution transport, nutrient storage, carbon sequestration and microbial activity. Differences in heterogeneity of internal aggregate structure can help explain spatial variability in these soil processes. Through the application of fractal tools, such as box-counting fractal dimension, one can understand the heterogeneity present within soil aggregate pore structures. Greater heterogeneity will result in a higher box-counting fractal dimension, but so will increased porosity. Due to this, a method of accounting for differences in porosity is needed when comparing the fractal dimension of different aggregates, especially those coming from contrasting land use and management practices.

## Objectives

There are three primary objectives of this study:

**(i)** Develop a method of standardizing the box-counting fractal dimension to account for differing porosities;

**(ii)** Use computed tomography scanning and fractal analysis to examine the characteristics of the intra-aggregate pore space in macro-aggregates

**(iii)** Compare heterogeneity of the intra-aggregate pore space in macro-aggregates from the same soil that have been subjected to long-term contrasting management practices, namely conventional tillage, no-till and native succession vegetation.

## Materials and Methods

Study site:
Kellogg Biological Station Long-term Ecological Research (KBS LTER) main site established 1988, Michigan, USA

Soil:
Well-drained Typic Hapludalf developed on glacial outwash

Treatments:
Conventional Treatment (CT) – corn-soybean-wheat rotation with conventional chemical input and chisel plow
No-Till (NT) – corn-soybean-wheat rotation with conventional chemical input and no-till
Native Succession (NS) – abandoned from agricultural use in the spring of 1989

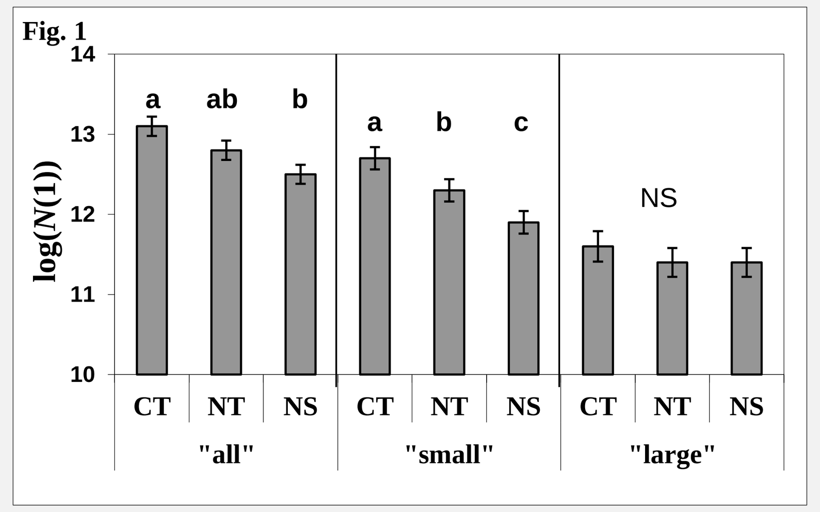
Aggregates:
Sampled from depth of 0-20cm, size 4-6 mm, 15 per treatment

CT scanning:
APS Argon National Laboratory with scanned resolution 14.6µm

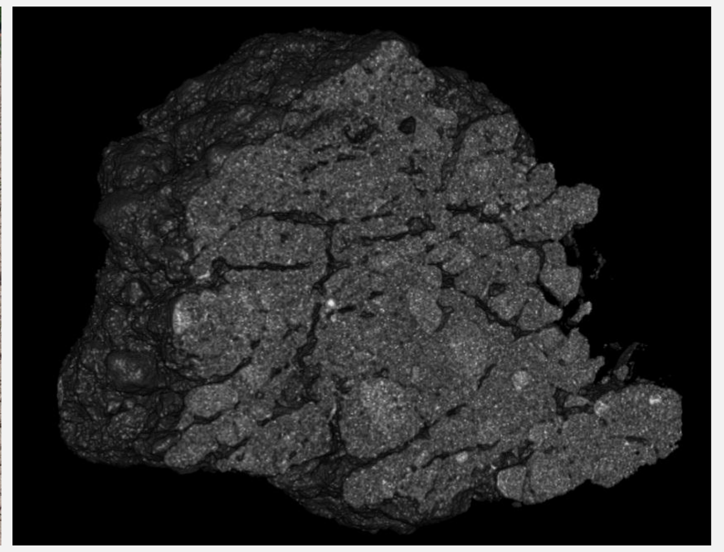
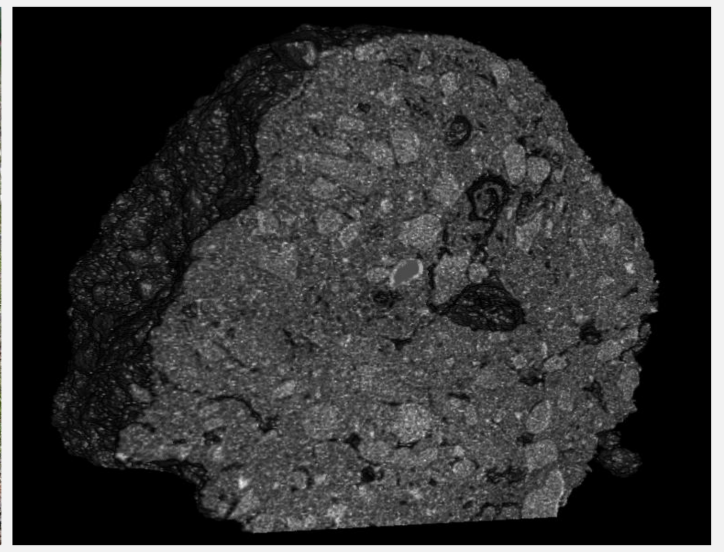
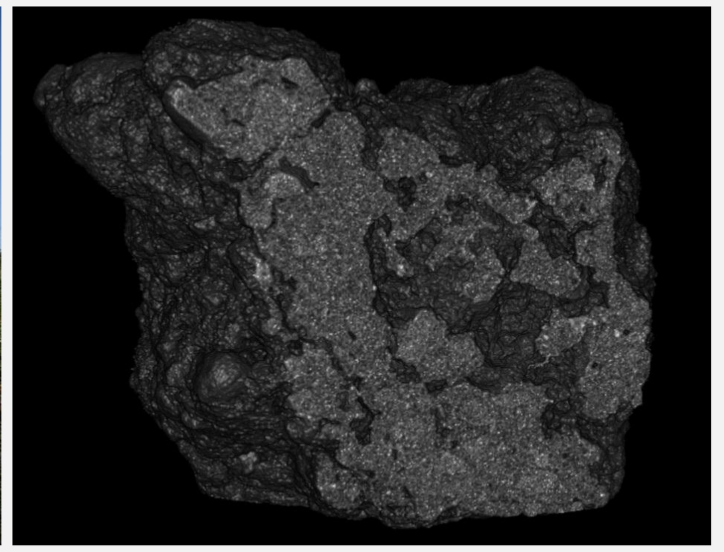
Pore segmentation:
Images were segmented by Indicator-Kriging in 3DMA-Rock

Pore categories:
All pores >15 µm
Small pores 15-60 µm
Large pores >105 µm

Fractal dimensions were calculated by classical box-counting method, with standardization described on the far right. Figure 1 shows that the different treatments had significantly different number of pore voxels, log(N(1)), which indicates that standardization will be necessary.

Fig. 1



## KBS LTER Treatments

| | Field Conditions Before Planting<br>photo credit to:<br>J.E. Doll/KBS-MSU | Typical Aggregate |
|---|---|---|
| CT |  |  |
| NT |  |  |
| NS |  |  |

## Standardization of Box-Counting Fractal Dimension

Classical fractal dimension, $D_0$, was calculated according to equation (1) for the linear portion of the graph (see figure 2). Relative dimension, $D_r$, was calculated according to equation (2), which accounts for the initial porosity of an aggregate. In this equation, $D_d$ is is calculated as the ratio of log(N(1)) and log($\delta_{max}$) (see figure 3). For our aggregates, the maximum box size was relatively constant, meaning different values of $D_d$ just reflect different initial porosities.

$$(1) \qquad N(\delta) \propto \delta^{-D_0}; \quad \delta = 1,2,\ldots n$$

$$(2) \qquad D_r = \frac{D_d - D_0}{D_d}$$

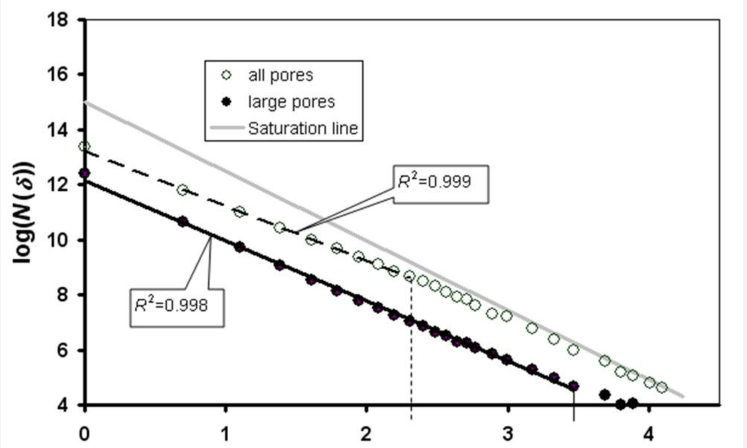


Fig. 2

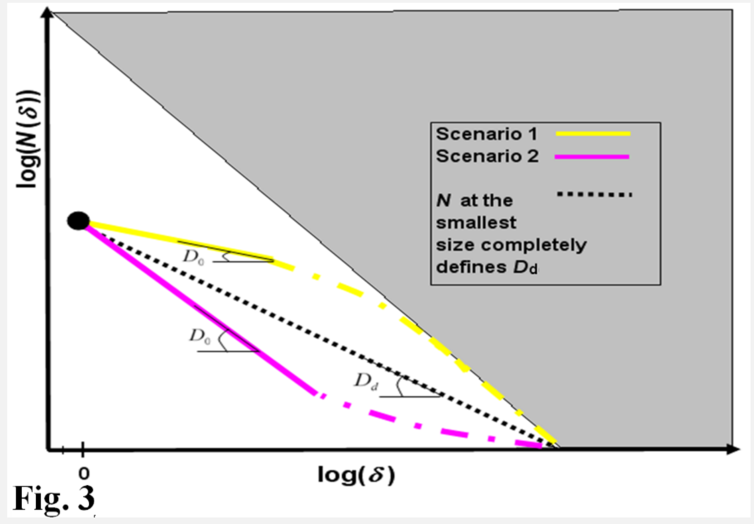


Fig. 3

## Results

Using relative fractal dimension values, it was shown that large pores are more heterogeneous in native succession and no-till aggregates than ones from the conventional tillage treatment, while classical fractal dimensions are not statistically different. Also, using the relative dimension, there were no differences in small pore distributions.

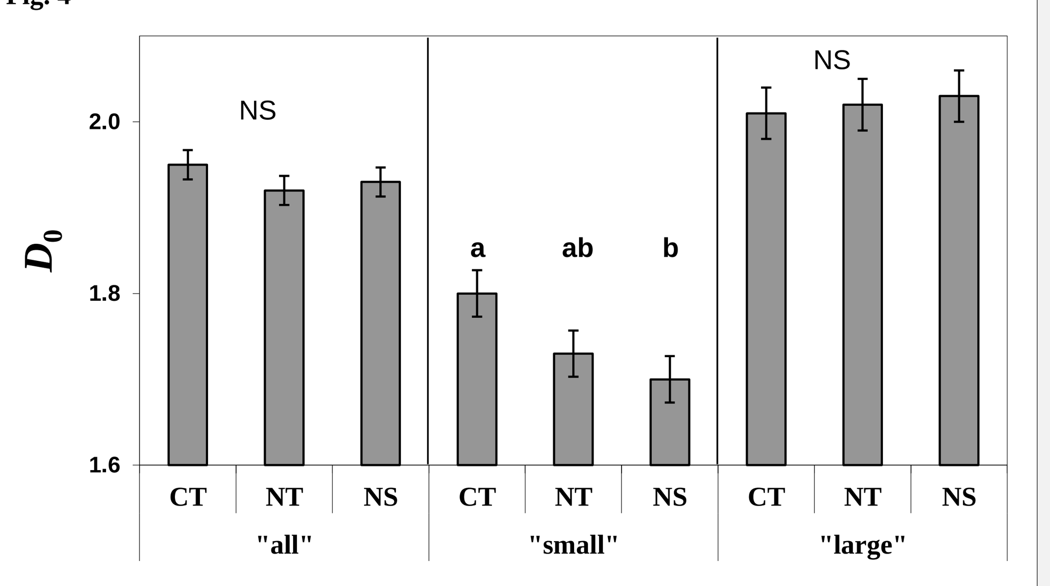
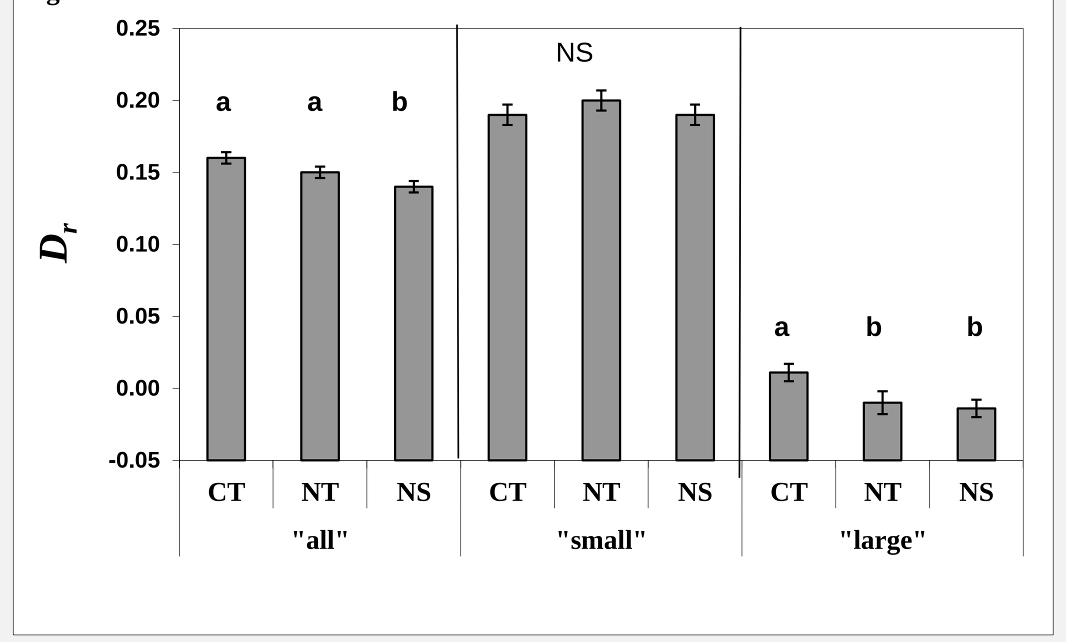
Fig. 4



Fig. 5



## Conclusions

Aggregates subjected to conventional tillage tend to have higher porosities, which inflate fractal dimensions, but after accounting for porosity, it was shown that they have a more homogeneous distribution of large pores than either no-till or native succession.

## Acknowledgement

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