Representative Elementary Volume for Pore System Geometry Parameters Determined from 3D X-Ray Images

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Introduction and Objective

Microtomography has been used in soil physics for characterization and allows non-destructive analysis with high-resolution, yielding a three-dimensional representation of pore space and fluid distribution. It also allows quantitative characterization of pore space, including pore size distribution, shape, connectivity, tortuosity and orientation. 3D microtomography images request an acquisition time for obtaining the image, processing and analyses. The other problem associated is the file size, larger files demands higher computational power. Thus, determination of the Representative Elementary Volume (REV) of 3D microtomography images is interesting since it can reduce computational time without the loss of information. The REV is the smallest volume over which a measurement can be made that will yield a value representative of the larger system.

Knowing the REV allows minimizing the sample size to acquire and analyze the images, and consequently the time needed for the analyses; we determined the REV related to four image parameters in four Brazilian tropical soils using 3D X-ray microtomography images with a spatial resolution of 40 µm.

Material and Methods

Four tropical soils from Brazil were collected, two in Jundiaí - SP (a Ferralsol (F) and a Lixisol (L)) and two soils in Piracicaba – SP (a Xanthic Ferrasol (XF) and a Rhodic Nitossol (RN)). Large undisturbed soil samples (height 7.5 cm; Diameter 7.5 cm) were collected in PVC rings.

We determined the REV related to four soil parameters (gamma, sum of pore surface area density, porosity and Euler density) using 3D X-ray microtomography images with spatial resolution of 40 µm. The 3D X-ray microtomography images were obtained with a Nikon XT H 225 CT system and software CT Pro 3D (Nikon) was used to reconstruct the image. Image processing was performed using the FIJI/Image J software in subsamples at different sizes were made with the original binary images, to obtain images with different volumes. To do so, the subsequent image had your volume reduced in 50%, (from 7,912.70 mm³ to 14.83 mm³). For each size, the standard deviation of the obtained values was obtained. The REV was determined as the smallest size corresponding to a low standard deviation. The sum of pore surface area density were calculated by adding the superficial area of each pore then divided by image volume. Euler number is used for describing the connectivity of spatial structures, so the values were divided by image volume to obtain the Euler density. Gama is an indicator of macropore and connectivity.

Results and Discussion

Table 1. Soil physical properties, average followed by standard deviation

Characteristics	F	L	X.F	R.N
Bulk density D_b (g cm^{-3})	1.506 (0.09*)	1.336 (0.09*)	1.851 (0.05*)	1.547 (0.06*)
Particle density D_p (g cm^{-3})	2.548 (0.07*)	2.548 (0.03*)	2.590 (0.06*)	2.730 (0.14*)
Saturated hydraulic conductivity K_s (cm d^{-1})	285 (174*)	315 (288*)	3.0 (4.9*)	62.4 (36.3*)
Particle size distribution				
Sand content (kg kg^{-1})	0.603	0.678	0.754	0.346
Silt content (kg kg^{-1})	0.071	0.076	0.024	0.253
Clay content (kg kg^{-1})	0.326	0.246	0.222	0.401
Soil classification				
	Ferralsol	Lixisol	Xanthic Ferralsol	Rhodic Nitosol

*SD = standard deviation

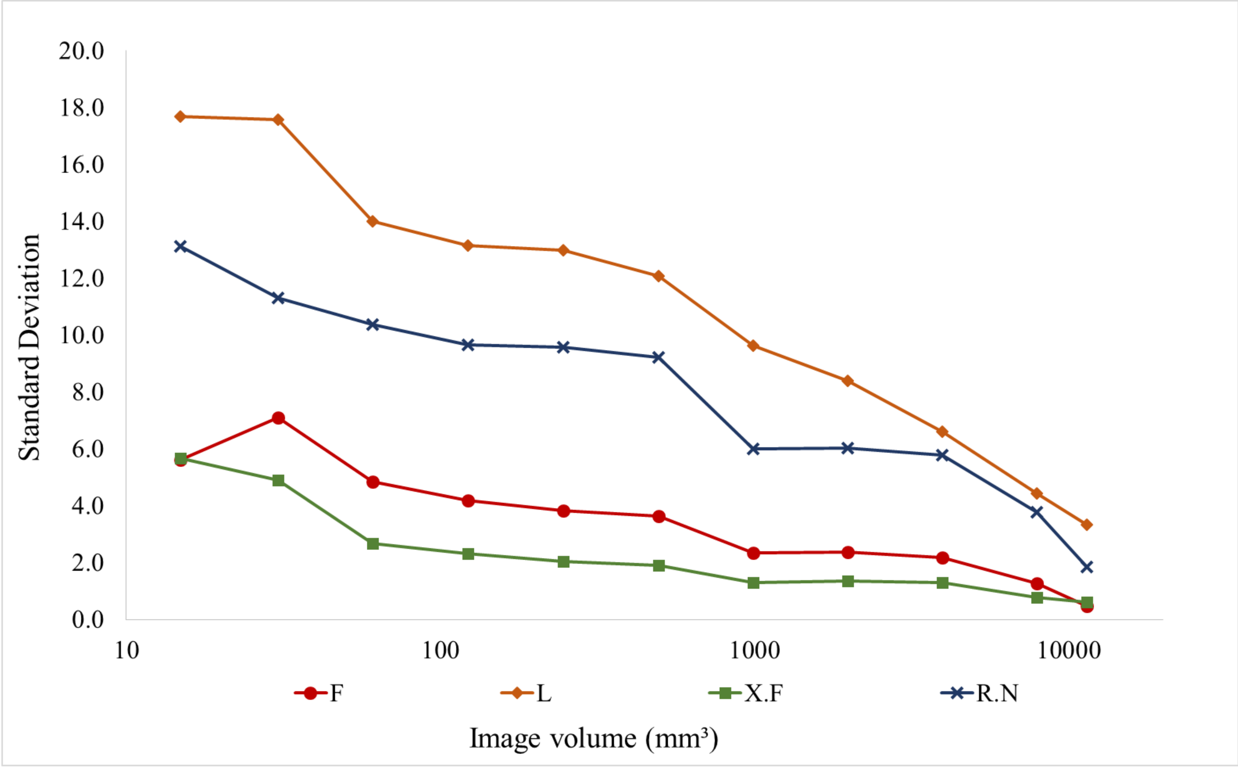

Figure 1. Image volume versus standard deviation of gamma

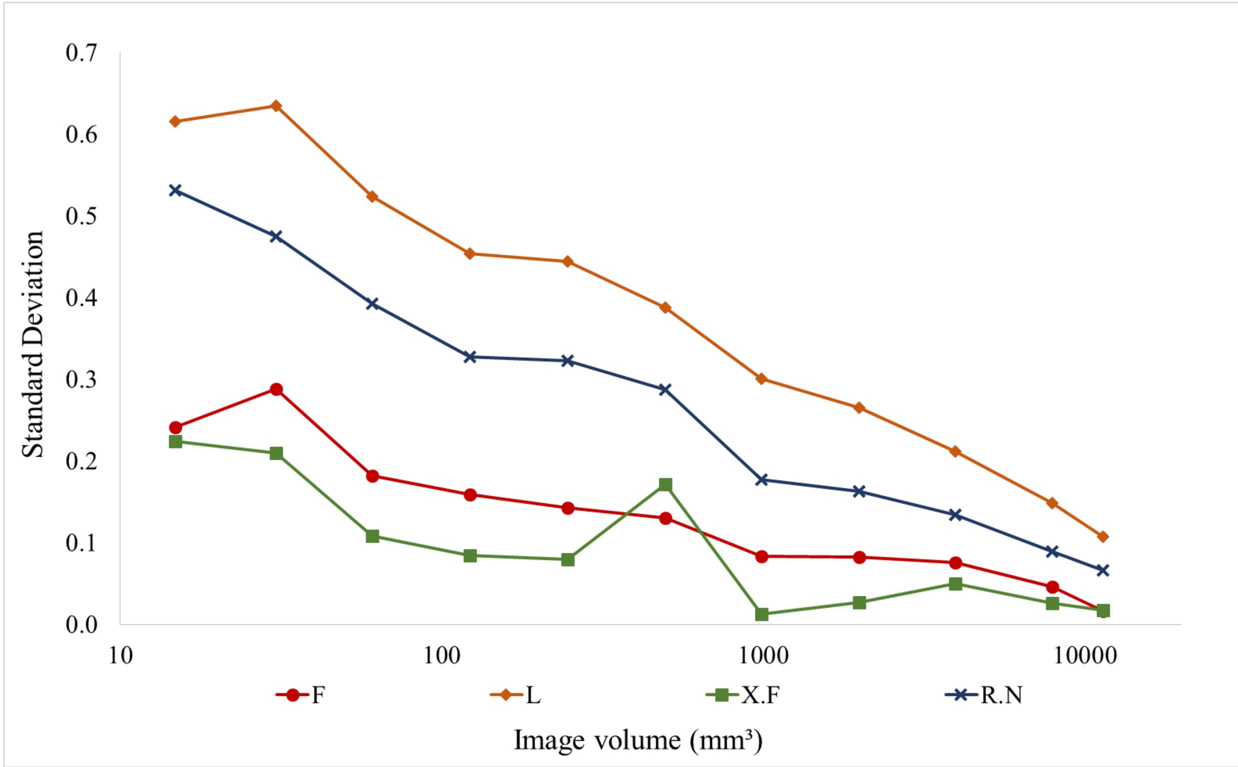

Figure 2. Image volume versus standard deviation of sum of pore surface area density (mm^{-1})

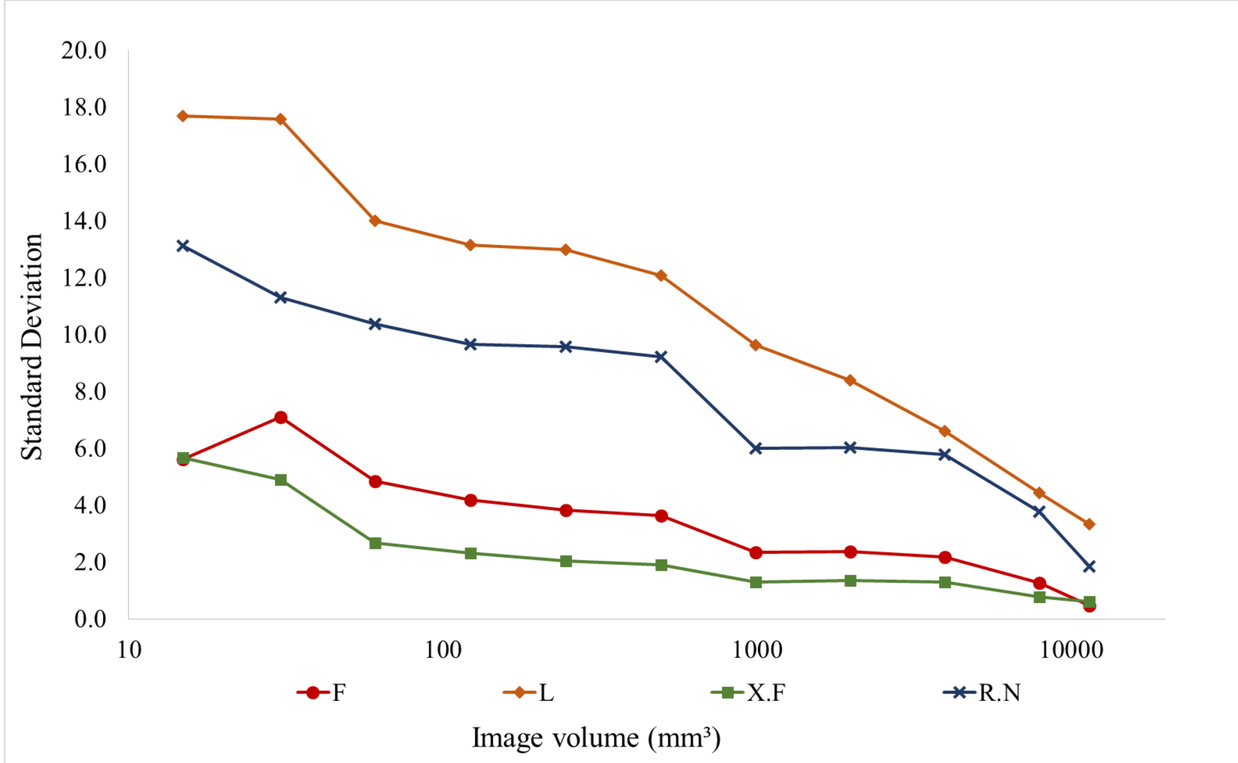

Figure 3. Image volume versus standard deviation of porosity

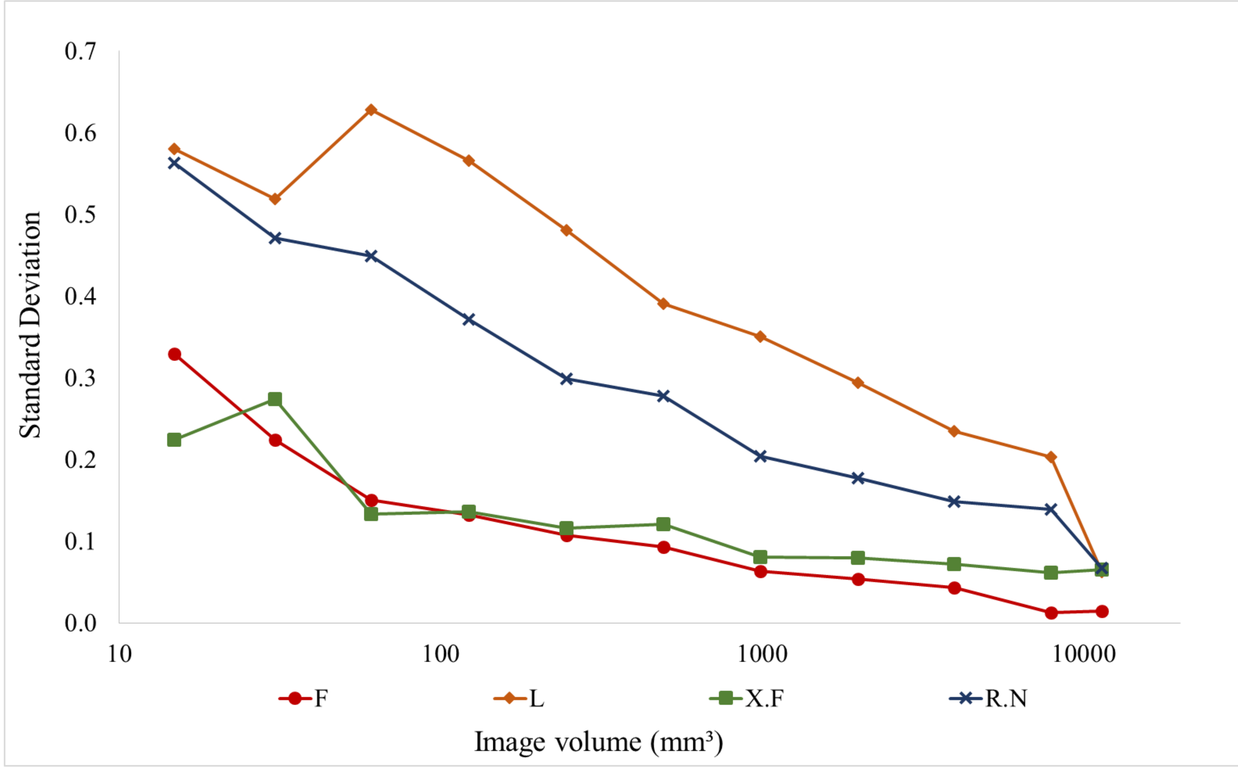

Figure 4. Image volume versus standard deviation of Euler density

Conclusions

For the soils analyzed and for the image spatial resolution used, REV was not achieved for none of parameters analyzed.

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