A comparison of the differences in soil structure under long-term conservation agriculture relative to a secondary forest

Supplementary Material

Soil samples were collected in experimental areas under no-tillage (NT), minimum tillage (MT), and secondary forest (SF), as shown in Figure S1.

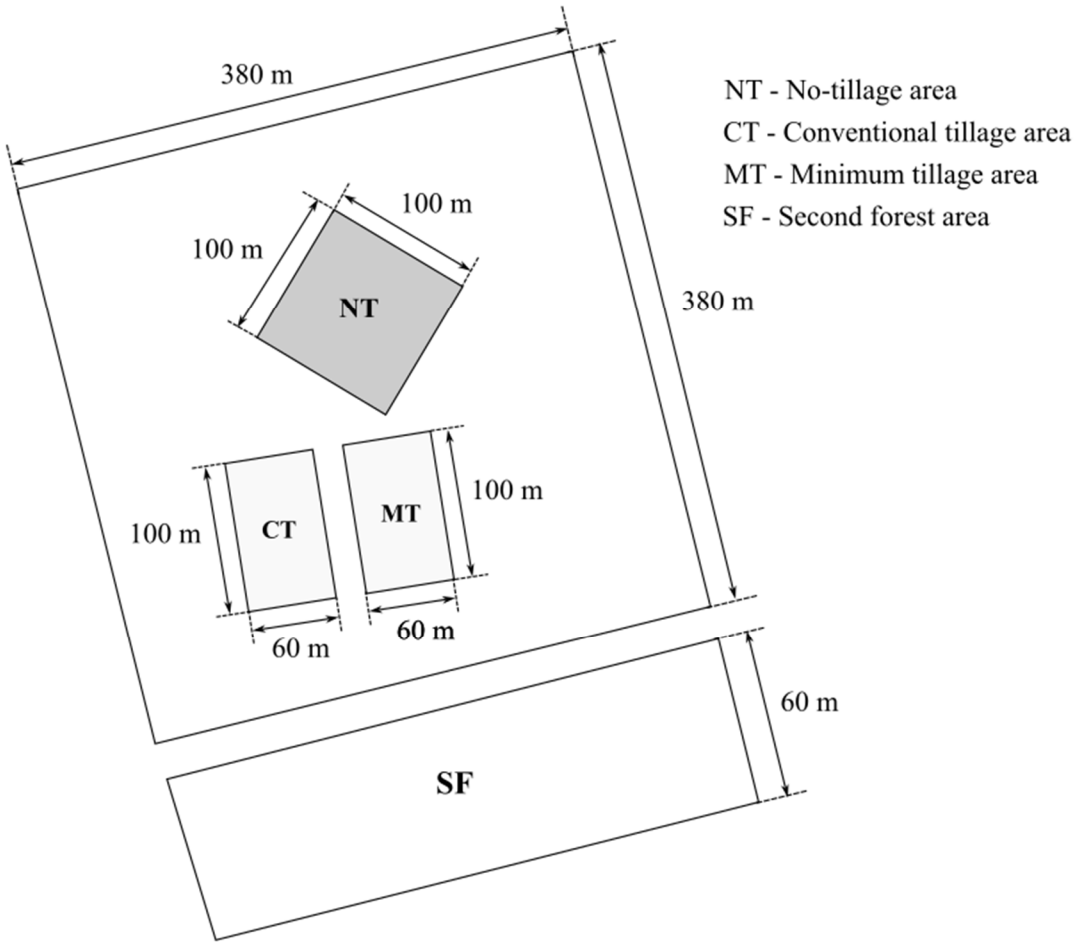


Figure S1. Schematic representation showing the experimental areas under no-tillage (NT), minimum tillage (MT), and secondary forest (SF).

In the image processing step, the raw images were cropped, pre-processed using filters, and then segmented into two phases, air (pores) and solids (soil matrix). Next, each segmented two-dimensional image was used to generate the three-dimensional (3D) images of the soil samples studied. Figure S2 shows a schematic diagram of the steps followed in image processing.

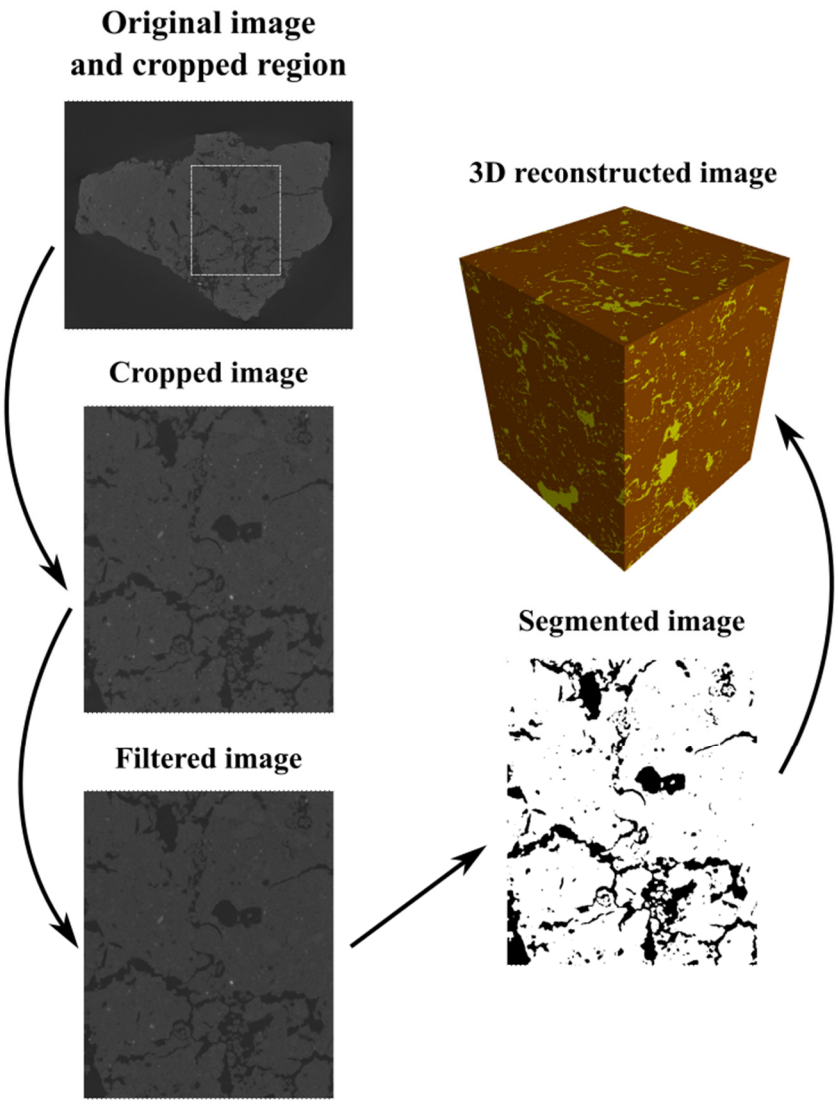


Figure S2. Schematic representation of the procedures performed in the segmentation of the soil samples. The image shows the result for only one two-dimensional (2D) section of one of the samples under the secondary forest area (SF).

The classification of the pores based on their shapes was made considering the major (L), intermediate (I), and minor (S) axes of the ellipsoids representing each pore in the 3D images (Figure S3). Thus, the pore shape classification was performed considering the relations between the ellipsoid axes (I/L and S/I). Although several pore shapes can be classified in 3D, in our study, we have determined only the following shapes: Equant (EQ), Prolate (PR), Oblate (OB), and Triaxial (TR).

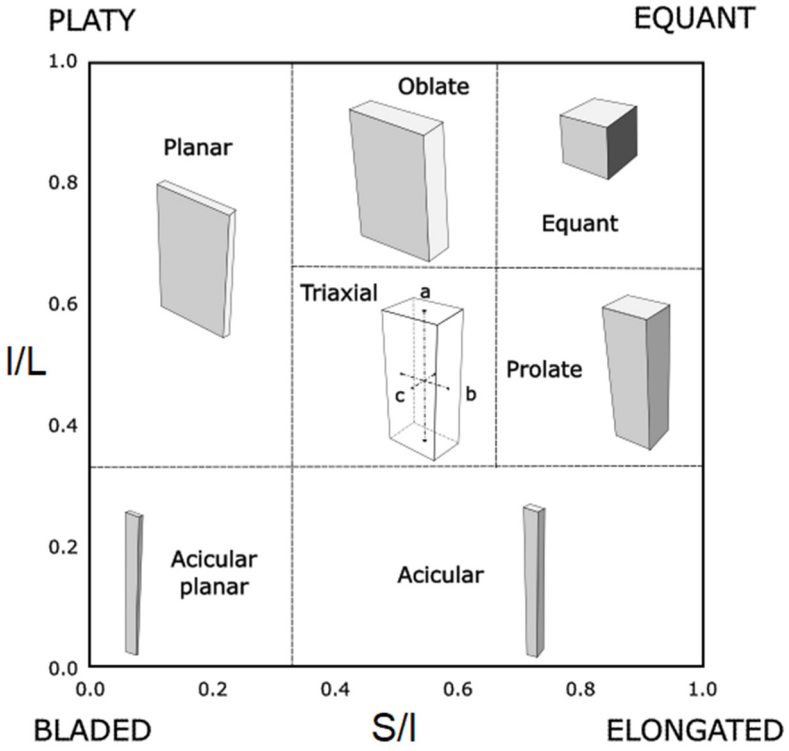


Figure S3. Classification of the soil pores based on their shapes.

The combination of the indices (ratio between the ellipsoid axes) shown in table S1 was utilized to determine the 3D pore shapes. When the pores have the highest ratio values between the indices, they have a shape that approaches that of a sphere. Conversely, when lower values of these ratios are determined, it indicates that the pores become more elongated in shape and thinner.

Table S1. Indices (I: intermediate axis, L: major axis, and S: minor axis) that were used for the shape-based pore classification.

Shape	**Axes ratio**	
	I/L	**S/I**
Equant (EQ)	≥2/3	≥2/3
Prolate (PR)	<2/3	≥2/3
Oblate (OB)	≥2/3	<2/3
Triaxial (TR)	<2/3	<2/3

Figure S4 shows the result of the correlation analysis, considering both analyzed managements (no-tillage and minimum tillage) and the area under the secondary forest. All parameters obtained by the tomography analysis were used in the correlation analysis.

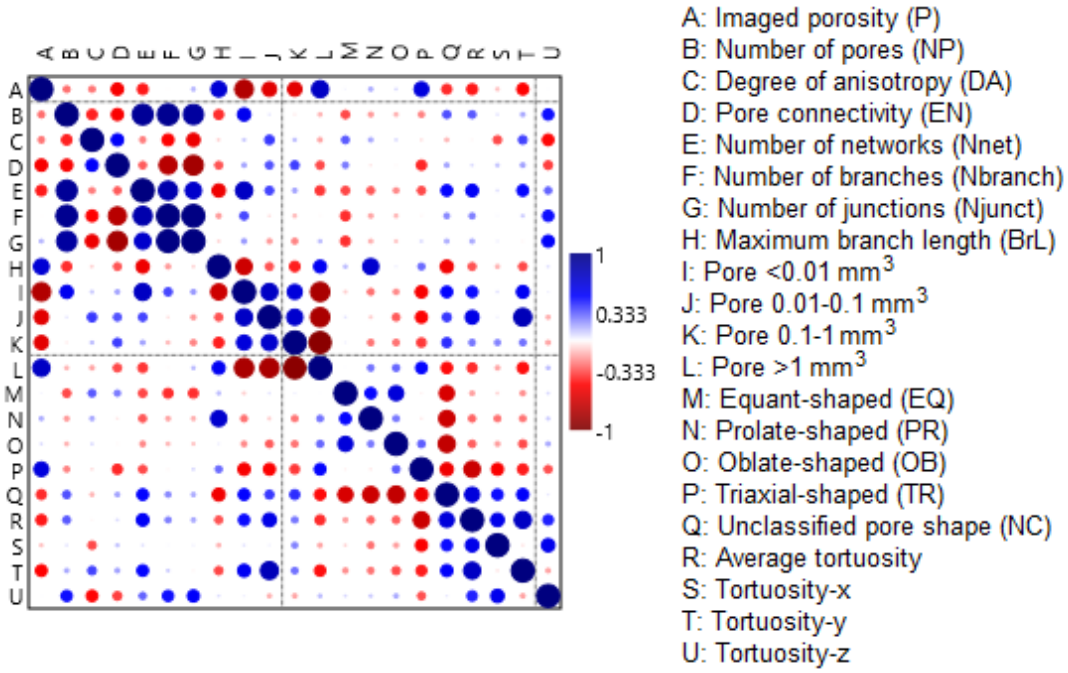


Figure S4. Schematic showing the result of the correlation analysis for the different soil morphological parameters obtained by microtomography analysis. The cold colors indicate positive correlations, while the hot colors indicate negative correlations between the analyzed variables.

The analysis of correlation (Figure S4) showed us that the porosity was positively related ($p<0.05$) to the maximum branch length (BrL) (r=0.67), the largest pores analyzed (>1 mm^3) (r=0.73), and the triaxial shaped pores contribution (r=0.63). On the other hand, negative correlations were found between the porosity and the pore connectivity (EN) (r=-0.53) and pore size classes ranging from 0.01 to 0.1 mm^3 (r=-0.61) and from 0.1 to 1 mm^3 (r=-0.61). The number of pores (NP) was negatively related with the pore connectivity (EN) (r=-0.52) and positively related with the number of network (r=0.90), branches (r=0.93), junctions (r=0.87), and the smallest pores (<0.01 mm^3) (r=0.56). The degree of anisotropy (DA) was positively related to only the pore connectivity (r=0.52) and inversely related to the number of branches (r=-0.50) and junctions (r=-0.57). The pore connectivity (EN) was inversely related to only the number of branches (r=-0.77) and junctions (r=-0.86). The number of networks was positively related to the number of branches (r=0.82), junctions (r=0.70), the smallest pore sizes (<0.01 mm^3) (r=0.73), the non-classified pores (r=0.49), and the average tortuosity (r=0.53). A negative relation was found between the number of network and the maximum branch length (r=-0.56). The number of branches was positively related to only the number of junctions (r=0.98). The maximum branch length was positively related to the largest pore sizes (r=0.54) and negatively related to the smallest ones (r=-0.69). The smallest pore sizes were positively related to the non-classified pore

types (r=0.50) and the average tortuosity (r=0.48) and negatively related to the triaxial-shaped pores (r=-0.52). The same was noticed for the pore size classes between 0.01 and 0.1 mm^3, presenting negative correlations against the triaxial-shaped pores (r=-0.51) and positive against the average tortuosity (r=0.59). The largest pore sizes presented a positive relationship with the triaxial-shaped pores (r=0.49) and an inverse relationship with the non-classified pores (r=-0.48). Finally, the non-classified pores were positively related to only the average tortuosity (r=0.64).