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Soil organic carbon, macropore networks and preferential transport

Mats Larsbo (1), John Koestel (1), Thomas Kätterer (2), and Nick Jarvis (1)

(1) Swedish University of Agricultural Sciences (SLU), Soil and Environment, Uppsala, Sweden (mats.larsbo@slu.se), (2) Swedish University of Agricultural Sciences (SLU), Department of Ecology, Uppsala, Sweden

Agricultural management practices such as tillage, crop rotations, residue management and fertilization can have a strong influence on soil organic carbon (SOC) stocks. An increase in SOC content will generally improve soil structure, which in turn determines the solute transport pathways through the soil. The aim of this study was to quantify the architecture of macropore networks in undisturbed soil columns (15 cm high, 12.7 cm diameter) sampled along a transect with natural variations in SOC using X-ray tomography and to relate the network characteristics to the degree of preferential transport in the columns. Two tracer experiments were carried out at constant irrigation rates of 2 and 5 mm h-1. We used the normalised 5% arrival time which reflects the tendency for early arrival of the solutes as a measure of the degree of preferential transport. The soil macropore networks were analysed in cylindrical sub-volumes (8 cm high, 10 cm diameter) located centrally within the soil columns. These sub-volumes were considered unaffected by sampling artefacts. Analyses were also carried out the for whole sample volumes to enable comparisons with the results from the transport experiments. Image processing and analysis were carried out in ImageJ and R. The same grey value threshold was applied to all images after harmonisation of grey values using the PVC column walls and the air outside the columns. This approach resulted in a satisfactory separation between the pore space and the surrounding soil matrix and organic matter. The SOC content along the transect, which varied from 4.2 to 15% , was correlated to all measures of the pore network for the sub-volumes except for the connectivity probability. Columns with high SOC content were associated with large macroporosities (both total and connected), large specific surface areas, large fractal dimensions and small mean pore thicknesses. The SOC content for whole sample volumes was positively correlated to 5% arrival times at both flow rates. As far as we know, this is the first time a direct relationship between SOC content and the degree of preferential transport has been clearly established. We have thus demonstrated that the fundamental effects that SOC has on soil structure also strongly reduce preferential transport. Management practices intended to promote SOC sequestration to mitigate climate change may, therefore, have additional benefits in reducing risks of water pollution.