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Contrast agents and X-ray μCT scan for particulate organic matter detection inside repacked soil cores

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Soil organic matter plays a key role in soil structure formation, although the bidirectional relationship existing between organic matter and soil pore network is complex and needs further investigations. The knowledge gap is due to technical limitations to study the microscopic organic phase-pore network arrangement as well as their temporal dynamics. Despite potentials offered by X-ray computed microtomography (μCT), only few studies used this technique to investigate spatial location of organic compounds within the soil matrix. Indeed, results are based on the X-ray linear attenuation coefficient (α), and mixture of organics with soil mineral fractions implies overlapping of information that makes any segmentation procedure inefficient. Some Authors proposed several possible contrast agents that could increase organic phase mass (i.e. α) simplifying threshold operation. By using silver nitrate ($AgNO_3$) and phosphomolybdic acid (PMA) as contrast agents, the aim of this study was to visualize, segment and quantify particulate organic matter (POM) inside the soil matrix through X-ray μCT. Moreover, manual, Otsu, Isodata, 2D kriging (2DK), 3D kriging (3DK), multi-region kriging (MRK) and superviosioned grey value-based approach (GV) performances were evaluated in both terms of organic matter content estimate and morphology identification. A silty loam soil was air-dried, sieved and placed in a muffle furnace (550 °C, 4 h) for organic matter removal. Maize silage (50-2000 μm sieved) was used as POM input, marked with both $AgNO_3$ and PMA and added into the soil in two concentrations (w/w), 1% and 5%. Two series of soil cores were repacked: “dry” (1.2 g cm-3 BD) and “wet” (1.4 g cm-3 BD with 38% volumetric water content). Successively, soil samples were subjected to X-ray μCT scan with a 7-μm image resolution.

Results showed that both $AgNO_3$ and PMA increased α of POM, simplifying its identification and the following segmentation. POM was discriminated from the mineral phase and its content correctly estimated when applying manual thresholding, Otsu, Isodata and GV approaches. Different thresholding algorithms affected also particles morphology. It was pointed out that the higher the object shape simplicity, the easier its segmentation for thresholding algorithms. Moreover, wet cores were exposed to washing-out phenomena that compromised any digital image processing and further POM quantification.

Improvements are thus required in order to increase the efficiency of automated thresholding algorithms and, in addition, more effort should be made to find other suitable staining agents (Research funded by PROTINUS H2020 project N°645717).