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3D-printing of undisturbed soil imaged by X-ray

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The unique pore structures in Soils are altered easily by water flow. Each sample has a different morphology and the results of repetitions vary as well. Soil macropores in 3D-printed durable material avoid erosion and have a known morphology. Therefore potential and limitations of reproducing an undisturbed soil sample by 3D-printing was evaluated.
We scanned an undisturbed soil column of Ultuna clay soil with a diameter of 7 cm by micro X-ray computer tomography at a resolution of 51 micron. A subsample cube of 2.03 cm length with connected macropores was cut out from this 3D-image and printed in five different materials by a 3D-printing service provider. The materials were ABS, Alumide, High Detail Resin, Polyamide and Prime Grey. The five print-outs of the subsample were tested on their hydraulic conductivity by using the falling head method. The hydrophobicity was tested by an adapted sessile drop method.
To determine the morphology of the print-outs and compare it to the real soil also the print-outs were scanned by X-ray. The images were analysed with the open source program ImageJ. The five 3D-image print-outs copied from the subsample of the soil column were compared by means of their macropore network connectivity, porosity, surface volume, tortuosity and skeleton. The comparison of pore morphology between the real soil and the print-outs showed that Polyamide reproduced the soil macropore structure best while Alumide print-out was the least detailed. Only the largest macropore was represented in all five print-outs. Printing residual material or printing aid material remained in and clogged the pores of all print-out materials apart from Prime Grey. Therefore infiltration was blocked in these print-outs and the materials are not suitable even though the 3D-printed pore shapes were well reproduced. All of the investigated materials were insoluble. The sessile drop method showed angles between 53 and 85 degrees. Prime Grey had the fastest flow rate; the other conducting materials had slow or non-reproducible flow rates. Since only Prime Grey was able to print-out the largest macropore in a discontinuous way, the morphological differences between the five print-outs were not evaluated.
Each material has its limitations but only Prime Greys morphology was sufficiently printed and no clogging with residual material occurred. Polyamide and High Detail Resin had clogged pores but were matching the soil's macropore morphology better but further research on removal of residual material blocking pores is needed before they are useable.