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Pore connectivity across scales and resolutions

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An important parameter to quantify pore structure and link it to soil functions is connectivity. When quantifying connectivity with X-ray microtomography (X-ray-µCT), one of the major drawbacks is that high resolution can only be achieved in small samples. In these samples, the small pores can be described, but the connectivity of larger pores cannot be quantified reasonably.

Here we explore changes in pore connectivity with changing sample size covering a range of analyzed pore diameters of more than three orders of magnitude. Soil columns with a diameter of 10 cm were taken in two different depths (0 - 20 cm and 40 - 60 cm) at different sites of an agricultural chronosequence ranging in age from 0 to 24 years. X-ray CT was used for scanning the original columns as well as undisturbed subsamples of 3 and 0.7 cm diameter. This enabled us to detect characteristic traces in certain connectivity metrics on the chronosequence, caused by different pore types and thus different processes. In detail, we determined the connection probability of two random points within the pore system, i.e. the Γ-indicator and the Euler number, χ as a function of minimum pore diameter.

Our results revealed that scale artifacts in the connectivity functions overlap with characteristic signatures of certain pore types. For the very first time a new method for a joint-Γ-curve was developed that merges information from three samples sizes, as the Γ-indicator gives highly biased information in small samples. In contrast, χ does not require such a scale fusion and is helpful to define characteristic size ranges for pore types. Overall, findings suggest a joint evaluation of both connectivity metrics to identify the contribution of different pore types to the total pore connectivity with Γ and to disentangle different pore types with χ.

For the samples of the chronosequence such an evaluation revealed that biopores mainly connect pores of diameters between 0.1 and 0.5 mm. However, this was not necessarily coupled with increasing porosity. Tillage, conversely, lead to an increase in porosity due to a shift of pores of diameter >0.05 mm towards pores of diameter >0.20 mm and therefore increased connectivity of pores >0.20 mm.

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