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Characterizing Nitrogen adsorption and desorption isotherms in soils using multifractal analysis

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The specific surface area is an attribute known to characterize the soil ability to retain and transport nutrients and water. A number of studies have shown that specific surface area correlates cation exchange capacity, organic matter content, water retention, aggregate stability and clay swelling. In the past fractal theory has been widely used to study different gas adsorption isotherms like water vapour and nitrogen adsorption isotherms. More recently we have shown that nitrogen adsorption isotherms showed multifractal nature. In this work, both N_2 adsorption and desorption isotherms measured in a Mollisol were examined as a probability measure using the multifractal formalism in order to determinate its possible multifractal behaviour. Soil samples were collected in two different series of an Argiudoll located in the north of Buenos Aires and in the south of Santa Fe provinces, Argentina. Two treatments of each soil series were sampled at three depths, without replication, resulting in six samples per soil series and a total of twelve samples analyzed. Multifractal analysis was performed using the box counting method. Both, the N_2 adsorption and desorption isotherms exhibited a well defined scaling behaviour indicating a fully developed multifractal structure of each isotherm branch. The singularity spectra and Rényi dimension spectra obtained for adsorption and also for desorption isotherms had shapes similar to the spectra of multifractal measures and several parameters were extracted from these spectra. The capacity dimension, D_0, for both N_2 adsorption and desorption data sets were not significantly different from 1.00. However, nitrogen adsorption and desorption data showed significantly different values of entropy dimension, D_1, and correlation dimension, D_2. For instance, entropy dimension values extracted from multifractal spectra of adsorption isotherms were on average 0.578 and varied from 0.501 to 0.666. In contrast, the corresponding figures for desorption isotherms were on average 0.761 with a range from 0.682 to 0.722. The entropy dimension D_1 is a measure of diversity in a multifractal system and it is also an index of the dispersion of the measure. The values of D_1 for adsorption isotherms were much lower than those for desorption isotherms. This indicates that for adsorption isotherms most of the measure concentrates in a small size domain of the study scale, whereas for desorption isotherms it was somewhat more evenly distributed. On the other hand, the Hölder exponent of order zero, α_0, was significantly greater for adsorption isotherms (1.396) when compared with desorption curves (1.246). Therefore, adsorption isotherms exhibit on average a lower degree of mass concentration (i.e. the lowest local density) than desorption isotherms. Moreover, the width of the singularity spectra was larger for adsorption than for desorption isotherms, which means a higher heterogeneity in the local scaling indices of the former variable. The potential usefulness in soil science of the multifractal characteristics extracted from the adsorption and desorption isotherms is discussed.

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