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Heterogeneity of soil properties along a profile as reflected in multifractal analysis

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Soils have been defined as natural bodies that have length, breadth and depth. Each soil type occupies a portion of the landscape. Soil properties are the result of soil forming factors and processes that operate at different spatial scales. Therefore, there is a need to take into account spatial scales and the processes operating at those scales for a sound characterization of the spatial variability of soil properties. The capability of multifractal analysis to efficiently describe and summarize patterns of soil spatial variability has been demonstrated in the last years. The objectives of this work were (a) to characterize the spatial variability and scaling of soil properties along a transect using multifractal techniques and (b) to relate the pattern of spatial variability with soil forming factors and processes. The research site was located at the experimental centre of the Agronomic Institute of Campinas, São Paulo State, Brazil. The topography of the site is gently undulating. The climate is humid subtropical (Cwa according to Köppen). A transect of 2370 m was established and a 30 m sampling interval was marked along it, giving 79 sampling points. This profile included different soil types and soil uses. The most frequent soil type was Oxisol according to the Soil Survey Staff equivalent to a Latossolo in the Brazilian classification system. Soil was sampled at the 0-20 cm depth and the following properties were determined: texture fractions, pH both in H_2O and KCl, organic carbon content (OC), exchangeable bases (S), exchangeable aluminium and hydrogen, cation exchange capacity (CEC) and percent base saturation (V). The texture along the studied transect ranged from clay to sandy-clay. Soil pH (H_2O) ranged from strongly acid (4.50) to neutral (7.00) with a mean value of 5.21. Accordingly percent base saturation varied between 4.0 % and 91.7 % and on average it was 38.2 %. Mean organic carbon content was 1.66% and the extreme values were 0.80 % and 2.60%. The statistical variability of the studied soil properties ranked as follows: V > silt > clay > S > OC content > sand > pH. The experimental data were converted into distributions of mass along a geometric support, i.e. mass content per segment of 30 m size, to perform multifractal analysis. Next, a probability distribution was obtained by dividing the values of the measure in a given segment by the sum of the measure in the whole transect. The spatial pattern of the studied soil properties showed multifractal scaling. Multifractal behaviour was well characterized and expressed through the next functions: singularity spectra, $f(\alpha)$, moment scaling exponent, $\tau(q)$, and generalized dimension, D(q). There were, however, differences in the degree of power law scaling between the studied soil properties. Our study showed that the multifractal parameters derived from f-α, τ-q and D-q relationships clearly summarized the spatial pattern of variability of the studied soil properties. The observed scale-dependent relationships demonstrate the usefulness of the multifractal techniques to analyze the effect of soil forming factors and processes on the patterns of soil spatial variability.

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