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Monitoring the soil degradation by Metastatistical Analysis

K. Oleschko (1), C. Gaona (2), and A. Tarquis (3)

(1) UNAM, Geosciences, Querétaro, Mexico (olechko@servidor.unam.mx), (2) Universidad Autónoma de Querétaro, División de Estudios de Posgrado, Facultad de Ingeniería, México, (3) Departamento de Matemática Aplicada a la Ingeniería Agronómica, E.T.S. de Ingenieros Agrónomos –U.P.M., Madrid, España

The effectiveness of fractal toolbox to capture the critical behavior of soil structural patterns during the chemical and physical degradation was documented by our numerous experiments (Oleschko et al., 2008 a; 2008 b). The spatio-temporal dynamics of these patterns was measured and mapped with high precision in terms of fractal descriptors. All tested fractal techniques were able to detect the statistically significant differences in structure between the perfect spongy and massive patterns of uncultivated and sodium-saline agricultural soils, respectively. For instance, the Hurst exponent, extracted from the Chernozem´ micromorphological images and from the time series of its physical and mechanical properties measured in situ, detected the roughness decrease (and therefore the increase in H - from 0.17 to 0.30 for images) derived from the loss of original structure complexity. The combined use of different fractal descriptors brings statistical precision into the quantification of natural system degradation and provides a means for objective soil structure comparison (Oleschko et al., 2000). The ability of fractal parameters to capture critical behavior and phase transition was documented for different contrasting situations, including from Andosols deforestation and erosion, to Vertisols high fructuring and consolidation. The Hurst exponent is used to measure the type of persistence and degree of complexity of structure dynamics. We conclude that there is an urgent need to select and adopt a standardized toolbox for fractal analysis and complexity measures in Earth Sciences. We propose to use the second-order (meta-) statistics as subtle measures of complexity (Atmanspacher et al., 1997).
The high degree of correlation was documented between the fractal and high-order statistical descriptors (four central moments of stochastic variable distribution) used to the system heterogeneity and variability analysis. We proposed to call this combined fractal/statistical toolbox Metastatistical Analysis and recommend it to the projects directed to soil degradation monitoring.
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