Geophysical Research Abstracts
Vol. 13, EGU2011-9634, 2011
EGU General Assembly 2011

Application of wavelet and fractal techniques to the analysis to soil structure and color

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The recent development of structured-light scanning technology especially multistripe laser triangulation (MLT) techniques has shown enormous promise in quantifying soil structure from intact soil specimens. The use of a MLT scanner in conjunction with visible-light (VIS) reflectance spectroscopy, which can be used to quantify soil color, has the potential to capture fine-resolution soil-morphological data at the pedon scale. The goals of our study were to (1) capture soil structure and color data with these technologies, (2) apply scaling techniques such as wavelets and fractals to the analysis of this data, and (3) interpret the results with the aid of traditional soil morphological descriptions. We applied these scaling techniques to three soil monoliths where data were collected from a MLT scanner and VIS reflectance spectrophotometer. The monoliths were previously taken from the Brownfield series [US Soil Taxonomy – loamy, mixed, superactive, thermic Arenic Aridic Paleustalfs; WRB – Luvisols (Profondic)], Amarillo series [US Soil Taxonomy – fine-loamy, mixed, superactive, thermic Aridic Paleustalfs; WRB – Luvisols (Profondic)], and Tillman series [fine, mixed, superactive, thermic Vertic Paleustolls; WRB – Luvic Chernozems (Profondic)] on the Llano Estacado of west Texas, USA. These soils represent varying soil colors and an increase in soil structural grade of the subsoil, respectively. Inputs into the wavelet and fractal analyses were topographic, spectral, and color data. Surface topography of the monoliths was obtained as irregularly-spaced xyz coordinates at a resolution of approximately 0.2 mm. These data were converted to a regularly-spaced matrix of z-values at a resolution of 0.5 mm using a local inverse distance weighting interpolation. Colors were quantified in the L*a*b* color space on a 2.5 cm-spaced grid spanning the surface of the monoliths. Reflectance spectral curves between 400 and 700 nm were measured at each point that color data were obtained. Color and spectral data were interpolated to a 5 mm resolution matrix using an ordinary kriging interpolation. Wavelet spectra were calculated for these data from the continuous wavelet transform. Hurst components were estimated from the slope of the log of the wavelet spectra and used to calculate the fractal dimension for each horizontal row. In addition, surface roughness (i.e. standard deviation of elevations) was calculated for each row in the z-value matrix. Results show that the variation of fractal dimension with depth for topographic data appeared to correlate with structure type. In addition, surface roughness measurements correlated with soil structural grade. These finds are important because subtle differences in structure type and grade are usually difficult to quantify. Spectral and color data analyses were much less conclusive likely owing to the coarse spatial resolution over which these data were obtained. Future work should: (1) center on the link between structure and fractal dimension variation with depth, (2) examine the correlation of direct measurements of roughness and structure, and (3) represent spectral and color data at finer resolutions. Analyses and discussions of practical issues centered on the deployment and promise of these novel technologies will be presented.