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Fractal analysis and graph theory applied to the spatial and temporal variability of soil water content

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Spatial and temporal variability of soil moisture content has been frequently evaluated using statistical and geostatistical methods for several issues. For example, the statistical study of the temporal persistence or temporal stability in spatial patterns of soil moisture content has found interest to improve soil water monitoring strategies and to correct the average soil water content for missing data. Fractal analysis and graph theory are additional tools that can provide information and further insight to assess and to model indirect or hidden interactions in soil moisture content. In fractal analysis the fractal dimension (D) is an indicator of the pattern and extent of spatial and/or temporal variability. Large D values indicate the importance of short-range variation, while small D values reflect the importance of long-range variation when spatial and temporal data sets are analyzed. Moreover, for spatial and temporal variability, D can range from 1 to 2 for a profile and from 2 to 3 for a two dimensional network. Moreover, as the fractal dimension value increases the degree of roughness also increases. Graph theory tools take into account network structure by modelling pair wise relations between objects, which allow considering explicitly spatial-temporal connectivity of a given data set. The objective of this study was to use fractal analysis and graph theory to characterize the pattern of spatial and temporal variability of soil moisture content. The experimental field was located at Ottawa, Canada. Volumetric water content was monitored using Time Domain Reflectometry (TDR) during 34 dates at 164 locations per date. The depth of the TDR probes was 20 cm. The first and last measurements were 21 month apart and no data were taken in winter when the soil was covered by snow. The fractal dimension, D, was estimated from the slope of the regression line of log semivariogram versus distance for each of studied data sets. Using graph theory various parameters were calculated from the data measured in the 164 experimental vertices including edges, disconnected pair's number, average degree and clustering, etc.; calculations were performed for 21 groups of sets measured during three successive dates. Fractal dimension, D, ranged from 2.589 to 2.910, so that the smallest and the largest values indicate domination of long- and short-range variation respectively. Interestingly there was no correlation between fractal dimension, D, and coefficient of variation. Highest D values were recorded in spring and summer time. Parameters derived from graphs also allowed discrimination of the structure corresponding to successive data sets measured in three successive dates. For example, clustering varied from 0.406 to 0.836, given a correlation coefficient of 0.995. Different degrees of connectivity corresponded to different seasons. Parameters derived from fractal analysis and graph theory were useful to characterize the pattern and extent of spatial and temporal variability of soil moisture content.

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