Concepts of “fractals” in soil science: demixing apples and oranges

Sixteen years after the first applications of the theory of fractals to soils (Burrough, 1981), and in spite of an impressive body of literature on the subject, this field of research still seems in its infancy. Arguably, one of the key factors hampering progress is the lack of a consensus on what it means for a soil to be or to behave “like a fractal”.

The (particularly constructive) exchange of views between Young et al. (1997) and Pachepsky et al. (1997), as well as the recent bibliographical review by Anderson et al. (1998), go a long way toward answering this question, and clarify many of the issues involved. Yet, in our opinion, they still leave the reader with considerable uneasiness about the proper way to handle “unphysical” fractal dimensions, which fall outside a range that is considered acceptable on physical grounds.

The confusion that might ensue is groundless, however, and can be easily dissipated if one realizes that there are currently two entirely distinct concepts of fractals in use in the soil science literature. This point, which goes beyond the recognition by Pachepsky et al. (1997) of the existence of different “fractal models”, does not appear to have been made explicitly in the relevant literature, except by Baveye and Boast (1998).

The original definition of fractals regarded them as geometrical constructs, i.e., as sets of points with a particular geometry, in a given space (e.g., $R^3$ or $R^n$). These fractals have a number of characteristic properties, chief among which is the (frequent) feature that they are geometrically similar to their parts (e.g., Baveye and Boast, 1998). Another property is that they lead to various power law relationships, i.e., Pareto distributions, for example between box sizes and number of boxes of specific sizes needed to cover the fractals completely. For these fractals, one may establish mathematically that

fractality $\rightarrow$ power-law behavior [1]

and that the fractal dimension is strictly constrained to be between the topological dimension of the fractal and the Euclidean dimension of the space in which the fractal is contained, for example between two and three for a surface fractal in three-dimensional space. When it is applied to physical objects (e.g., preferential flow patterns in Baveye et al., 1998), this concept of fractals cannot lead to “unphysical” fractal dimensions, unless the procedure used to evaluate the fractal dimensions is grossly inadequate.

The second concept of fractals, popularized by Turcotte (1986) in geology and used by a number of researchers in soil science (e.g., Rasiah et al., 1992; Borkovec et al., 1993; Logsdon et al., 1996; Kozak et al., 1996), has in general no connection with the first. It is based on the arbitrary postulate that

power-law behavior $\rightarrow$ fractality [2]

whatever option is adopted, authors who use fractal concepts should be asked to define clearly what kind of fractal they are using, and to strictly adhere to a consistent use of the term. Pragmatically, to avoid further confusion, it might be best to restrict the use of the term fractals to physical systems that, within observational scales, have geometrical properties similar to those of mathematical fractals. From this viewpoint, corresponding to the second type of fractal description of being called fractal could be labeled as paretoian, as is common in other fields (e.g., econometrics). Alternatively, following Crowelli and Barton (1995; see also in Baveye and Boast, 1998), one could distinguish geometrical fractals (first concept) and protological (second concept). Whatever option is adopted, authors who use fractal constructs or to physical systems that, within a range of observable scales, have geometrical properties similar to those of mathematical fractals.

References


