# Geostatistics in Soil Science: State-of-the-Art and Perspectives

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The last two decades have witnessed a growing use of geostatistics in environmental sciences, and more particularly in the processing of soil data. Until the late 1980s, geostatistics was essentially viewed as a means to describe spatial patterns through semivariogram analysis and predict the value of unsampled attribute values by kriging. Too often, soil geostatistics was confined to the application of tools originally developed by mining engineers to address mining topics. The emergence of a generation of truly soil geostatisticians, who can handle the complexity of both geostatistical theory and soil processes, allows one to tackle problems more specific to soil science, such as the incorporation of soil map information in prediction, the assessment of the uncertainty about soil quality parameters, or the modeling of space-time processes. In this paper I review the main applications of geostatistics, with an emphasis on recent developments in soil science, and point out challenging questions for the future.

The recent developments of data acquisition and computational resources have provided the geostatistician with a large amount of information of different types (continuous, categorical). Multivariate approaches, such as factorial kriging analysis, are increasingly used to investigate how the correlation between variables changes as a function of the spatial scale, and to improve our understanding of scale-dependent physical processes. On the other hand, multivariate geostatistical interpolation allows one to supplement a few expensive measurements of the attribute of interest (e.g., metal concentrations) by more abundant data on correlated attributes that are cheaper to sample (e.g., pH or elevation data). In particular, indicator geostatistics enables secondary categorical information such as provided by land use or soil map to be accounted for in the prediction of continuous variables.

There is necessarily some uncertainty about the attribute value at an unsampled location. The traditional approach for modeling local uncertainty consists of computing a minimum error variance (kriging) estimate and the associated error variance, which are then combined to derive a Gaussian-type confidence interval. A more rigorous approach is to assess first the uncertainty about the unknown, then deduce an estimate optimal in some appropriate sense. This can achieved using an indicator approach that provides not only an estimate but also the probability to exceed critical values, such as regulatory thresholds in soil pollution or criteria for soil quality. Another application is the evaluation of the risk involved in any decision-making process, such as delineation of contaminated areas where remedial measures should be taken or areas of good soil quality where specific management plans can be developed.

Another way to model uncertainty is to generate alternative images (realizations) that all honor the data and reproduce aspects of the patterns of spatial dependence or other statistics deemed consequential for the problem at hand. A given scenario (remediation process, land use policy) can be applied to the set of realizations, allowing the uncertainty of the response (remediation efficiency, soil productivity) to be assessed.