Geostatistical Estimation of Functional Form of Water Retention Curve: Parametric vs. Non-parametric Approach

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Because exhaustive sampling is impossible in most soil surveys under constraints of time and costs, we usually have only incomplete knowledge of soil hydraulic properties. Geostatistical interpolation techniques are thus used to estimate unknown values of those properties at unsampled locations from observations. Unlike water flow in saturated systems, prediction of variably saturated water flow in soils depends not only on knowledge about saturated hydraulic conductivity, but also on knowledge about functional relationships of soil properties such as the water retention function. The water retention curve is usually parameterized with a simple functional form. These available models are convenient as they reduce the number of variables (or parameters) significantly, compared to the number of measurements used to construct the original retention curve.

This study compares the performance of two approaches, parametric and non-parametric, on geostatistical estimation of the water retention curve. Water retention data used in this study are those in the Las Cruces trench site database (Wierenga et al., 1989), in which 450 soil samples were taken at nine layers with 50 equally spaced samples per layer, from a 24.6 m by 6.0 m trench wall. For 448 samples, soil water retention curves were determined with the water content measured at eleven pressure heads of 0, 10, 20, 40, 80, 120, 200, 300, 1000, 5000, and 15000 cm H_2O.

In the parametric approach (P), three standard water retention models; Brooks & Corey (BC), van Genuchten (VG), and log-normal pore-size distribution (LN); were first fit to each curve using an automated fitting code developed by Seki (2007). This procedure does not require a reasonable initial estimate of parameters, which is usually necessary to obtain optimum outcomes in standard fitting programs, such as the RETC code (van Genuchten et al., 1991). For each model, a cross validation procedure, in which one observation at a time is temporarily removed from the dataset and re-estimated from remaining data using ordinary kriging, was used to estimate parameters at each sampling location. Estimated parameters were then used to compute prediction errors (mean absolute error and mean square error) from calculated water contents and observed ones for corresponding eleven water pressure heads.

On the other hand, in non-parametric approach (NP), a cross validation procedure was used to directly estimate water content values for eleven pressure heads. After the retention curve was constructed, aforementioned three models were fit using the same automated procedure. Parameters obtained were then used to compute prediction errors. This full NP approach requires ordinary kriging to be performed eleven times, which is three times more effort than the P approach where only four parameters were considered. Therefore, we also investigated the impact of reducing the number of pressure head-water content pairs from eleven to six (0, 20, 80, 300, 1000, and 15000 cm H2O) on obtaining model parameters.

The results show that, at more than 80% of locations considered, prediction errors decreased when the VG model was used for the both NP approaches, while prediction errors decreased at more than 60% and 70% of locations for the LN and BC models, respectively. The main reason that the NP approach improves dramatically for the VG model is that the P approach for the VG model results poorly compared to other two models. For the P approach, the average of 448 mean absolute errors for the VG model was twice as much as that of the other two models. For the NP approach, all three models resulted in about the same prediction errors. In summary, this study shows that the commonly used parametric approach to geostatistically estimate water retention curves has to be conducted with extreme care despite its convenience. The NP approach, on the other hand, systematically leads to acceptable results.