From Pedo to Pedon: Towards the next generation of transfer functions to estimate saturated hydraulic conductivity

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Pedotransfer functions (PTFs) are widely used tools to predict soil properties across different spatial scales and are commonly built using regression-based techniques (e.g., multiple linear regression or regression trees) and, more recently, machine learning methods (e.g., artificial neural networks). In these techniques, soil material arising from different soil horizons are treated as independent samples despite the depth dependency that exists for horizons within individual pedons. Here we propose a new approach to build PTFs that takes into account the depth dependency of saturated hydraulic conductivity \((K_{sat})\) and refer to this type of depth-dependent PTFs as a “pedontranfer” function (PnTF). Slope \((\beta_1)\) and intercept \((\beta_0)\) parameters describing the relationship of log-scale \(K_{sat}\) with soil horizon depth were fit to pedons selected from the Pedogenic and Environmental DataSet (PEDS). The intercept parameter can be interpreted as the \(K_{sat}\) at a 0 cm depth (i.e., \(K_{sat}\) at the soil surface) and \(\beta_1\) as the rate of change of \(K_{sat}\) with respect to depth. In order to build the PnTF, we used field-based pedon information from PEDS, encompassing approximately 2,000 pedons and >13,000 soil horizons across the United States and estimated \(K_{sat}\) using a generalized Kozeny-Carman equation. Our results show a strong negative linear relationship between \(\beta_1\) and \(\beta_0\) \((r^2 = 0.80; P < 0.01)\). When we predicted the fitted line of the linear relationship between \(\beta_1\) and \(\beta_0\) using a multiple linear regression with different soil and climatological variables we found a significant \((P < 0.01)\) and direct relationship, with relatively good agreement \((R^2 = 0.38)\). Our results suggest that the PnTF approach represents a step forward in the development of the next generation of PTFs, although further research is needed to improve its precision and accuracy. We believe that PnTFs, in principle, have significant advantages over PTFs that should be of interest to the community of developers and users of Earth system and community land models. For example, soil \(K_{sat}\) at depth may be predicted from knowledge only of the surface \(K_{sat}\) since \(\beta_1\) can be predicted from \(\beta_0\). Future work should incorporate other soil databases in order to account for systematic biases of the different methods to measure or estimate \(K_{sat}\).