

The Gardner dual model: An extension of the exponential Gardner equation to calculate the relative hydraulic conductivity curve

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Abstract: Determination of the relative hydraulic conductivity curve $K_r(h) = K/K_s$ is a major issue in soil modelling (h is the suction and K_s the saturated hydraulic conductivity). This study proposes a model to represent $K_r(h)$, the so-called Gardner dual (GD) model. It extends the Gardner exponential model to h values greater than the transition suction (h_o), the suction value at the inflection point of the $K_r(h)$ curve in the log-log scale. The performance of the GD model was compared to that of the MVG [two-parameter (K_{ro} , L) Mualem-van Genuchten] model and a corresponding modified MVG model (MVGm) (Schaap and van Genuchten, 2006. A modified Mualem-van Genuchten formulation for improved description of the hydraulic conductivity near saturation. *Vadose Zone J.*, 5, 27-34). In 77 soils from the UNSODA database (the same used by the authors above) without evidence of macropore flow (fast flow) close to saturation, the GD model reduced the mean value of the root mean square error {RMSE, considering the log differences [$\log(K_{r,\text{predicted}}) - \log(K_{r,\text{measured}})$]} by 64% (from 0.525 to 0.191) in relation to the MVG model, and by 29% (from 0.269 to 0.191) in relation to the MVGm model. In these soils, the GD model was also more accurate than the MVG model in all suction ranges. The GD model is defined for two ranges ($h < h_o$ and $h > h_o$) and has three parameters [$f(\beta)$, h_o , S_k], but it has only two degrees of freedom, like the MVG model. Parameter $f(\beta)$ is a dimensionless shape index, $0 < f(\beta) < 1$; $10 \text{ cm} \leq h_o \leq 300 \text{ cm}$ in the study database; parameter S_k (dimensionless) is a measure of the depletion potential of the $K_r(h)$ curve. S_k and h_o allow the calculation of the macroscopic capillary length, a parameter already established in the literature. It is shown that the GD model parameters are highly dependent on the measurement of the $K_r(h)$ curve close to its inflection in the log-log scale. This is an experimental advantage, since the transition suction, h_o , has been demonstrated to be within a narrow wet range ($h_o = 10$ to 300 cm), which must favour the estimation of K_r in the whole suction range when $K_r(h)$ data are available only in the wet suction range.

Key Words: hydraulic conductivity curve, Gardner exponential model, Mualem-van Genuchten model