Analysis of 3D infiltration curves measured with disc infiltrometer in heterogeneous soil profiles: Sequential analysis of infiltration data and estimate of $\beta$

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The 3-D Haverkamp et al. (1994) model for disc infiltrometer measures on homogeneous media involves the following parameters: the soil sorptivity, $S$, the saturated hydraulic conductivity, $K_s$, the $\beta$ parameter and the $A = (\gamma S^2)/(r_d*\Delta \theta)$ term, where $r_d$ is the disc radius, $\Delta \theta$ is the soil water increase and $\gamma$ is proportionality constant. Fixed $\beta$ and $A$ values are commonly used in most cases. $S$, and $K_s$ can be estimated from the inverse analysis of a cumulative infiltration curve by fitting it the Haverkamp model. For practical reasons, Haverkamp implicit model is replaced by its 4-term ($4T$) approximate expansion for the transient state. The first part of this work analyzes the influence of layered soils on $K_s$ and $S$ estimates, and designs a new procedure, sequential Analysis of Infiltration curve (SAI), for treating infiltration curves impacted by soil layering. The SAI method analyzes a sequence of increasing dataset for a given infiltration curve and fits to the $4T$ expansions to estimate $K_s$, $S$. Then estimates and RMSE are reported as a function of the number of data points used for the fit. The method was applied on synthetic profiles with homogeneous loam soil, six layered profiles involving a 1, 2 and 3 cm thickness loam layer over silty or sandy loam soils, respectively. Erroneous estimates of $K_s$ and $S$ were obtained when the total infiltration curves were considered for the analysis, regardless of the presence of soil layering. In opposite, estimates were improved using the SAI method for the layered systems. The SAI method relies on the fact that the RMSE increases when the wetting front reaches the interface between the upper layer and the lower layer. Such increase allows (i) the detection of the soil heterogeneity, (ii) the determination of the optimum infiltration time, $t_o$, that corresponds to the minimum value of RMSE, and, (iii) accurate estimation the upper layer $K_s$ and $S$.

Taking use of the SIA procedure, the second part of this communication studied the relationship between $\beta$ and $A$, and proposed a new procedure to improve the estimate of $K_s$ and $S$ and
approach $\beta$. The analysis was applied on synthetic infiltration curves simulated on homogenous and layered columns. The results showed that different combinations of $\beta$ and $A$ resulted in similar $K_s$. Overall, optimization of $K_s$, $S$ and $A$ for different $\beta$ values showed that $\beta$ had an important effect on $A$ and $K_s$, but not on $S$ and RMSE. We propose approaching the optimum $\beta$ as the $\beta$ for which is closer to zero, where $A$ and $A_{\exp}$ are the optimized and measurable parameter, respectively. While the optimum $\beta$ is calculated, $K_s$ and $S$ are computed by applying the optimum $\beta$ to the respective quadratic $\beta(K_s)$ and $\beta(S)$ relationships. This methodology allowed improving the estimate of $K_s$ giving good approaches of $\beta$ (36% error) and omitting the erroneous praxis of using constant $\beta$ and $A$ values.