Abstract

KAMEL, a computer model for the vadoze zone water flow, is based on a conceptual and functional model of structured soil-water medium in which the hydro-structural equilibrium and kinetics are characterized by the shrinkage and swelling curves, respectively (Braudeau et al., 2004 and Braudeau & Mohtar, 2006). The shrinkage curve was used to represent and characterize the equilibrium state of the soil water medium and the swelling curve was used to represent the dynamics of the medium as it returns to equilibrium due to abrupt changes in moisture conditions.

This project aims at evaluating the KAMEL model using experimental data (Davidson et al., 1969). This will be followed by identifying the most sensitive parameters that showed relatively high fluctuations between models and the experimental data. Sensitivity analysis of those parameters will follow. Experimental results of simple soil column exercise will be used in this analysis.

Methodology

The following steps represent the methodology that will be followed in this study:

1. Davidson et al. presented bulk density, $h-\Theta$ data\(^1\), and $K-\Theta$ data\(^2\) for three soils\(^3\) at various depths. They also presented water flux leaving the soil profile vs. time ($q-t$) data for the three soils.
2. The fourteen pedostructure parameters (Table 1) needed for the characterization of the water and pedostructure interaction will be estimated from Davidson data. Estimation of the pedostructure parameters will be performed using an Excel worksheet (a brief methodology of the transfer functions will be presented as an appendix).
3. The obtained pedostructure parameters will form the input parameters for the KAMEL model.
4. A simple column case will be simulated with the initial condition being near saturation\(^4\) (depending on the difficulties that might arise and the number of simulations, the number of soils tested will be determined).

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\(^1\) Soil water pressure head, $h$ (cm) vs. volumetric soil water content $\Theta$ (cm$^3$/cm$^3$).
\(^2\) Hydraulic conductivity, $K$ (cm/day) vs. volumetric soil water content $\Theta$ (cm$^3$/cm$^3$).
\(^3\) The three soils are: (1) Yolo loam, located at the University of California Davis research station; (2) Miller silty clay, located at the Oklahoma State University agronomy research station at Stillwater; and (3) Cobb loamy sand, located at the Oklahoma State University Caddo county research station.
\(^4\) In Davidson et al., the soil surface of each soil was “ponded with water until no further change in soil-water pressure with depth within the profile was observed” (Davidson et al., 1969). Then, soil was covered with plastic in an attempt to prevent evaporation. Hydraulic gradients and hydraulic conductivities within
5. KAMEL simulation results will be compared with those measured and calculated by Davidson et al. in an attempt to evaluate KAMEL’s outputs.

6. Sensitivity analysis will be performed to the pedostructure basic parameters listed in Table 1. In addition, the sensitivity of soil’s initial condition will be tested.

7. The correlation between measured and simulated data will be scrutinized and tested for the four water pools \((w_{re}, w_{bs}, w_{st}, w_{ip})\).

8. A set of recommendations and concluding remarks will be provided.

Figure 1 provides a flow chart representing the methodology that will be adopted in this study.

### Table 1: The complete set of the pedostructure parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Curve</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>(V_D)</td>
<td>(\text{dm}^3/\text{kg}_\text{soil})</td>
<td>ShC</td>
<td>Pedostructure specific volume at wet state</td>
</tr>
<tr>
<td>(W_N)</td>
<td>(\text{Kg}<em>\text{water}/\text{kg}</em>\text{soil})</td>
<td>ShC</td>
<td>Pedostructure specific water content at point N</td>
</tr>
<tr>
<td>(W_M)</td>
<td>(\text{Kg}<em>\text{water}/\text{kg}</em>\text{soil})</td>
<td>ShC</td>
<td>Pedostructure specific water content at point M</td>
</tr>
<tr>
<td>(W_L)</td>
<td>(\text{Kg}<em>\text{water}/\text{kg}</em>\text{soil})</td>
<td>ShC</td>
<td>Pedostructure specific water content at point L (Saturation)</td>
</tr>
<tr>
<td>(K_N)</td>
<td>(\text{Kg}<em>\text{soil}/\text{kg}</em>\text{water})</td>
<td>ShC</td>
<td>Constant of equilibrium between (w_{bs}) &amp; (w_{re}) during drying</td>
</tr>
<tr>
<td>(K_M)</td>
<td>(\text{Kg}<em>\text{soil}/\text{kg}</em>\text{water})</td>
<td>ShC</td>
<td>Constant of equilibrium between (w_{bs}) &amp; (w_{st}) during drying</td>
</tr>
<tr>
<td>(K_{bs})</td>
<td>(\text{Kg}_\text{soil}\text{dm}^3/\text{soil})</td>
<td>ShC</td>
<td>Scaling ration between pedostructure and primary peds</td>
</tr>
<tr>
<td>(E_{ma})</td>
<td>Joules/\text{kg}_\text{soil}</td>
<td>TC</td>
<td>Potential energy of the external surface of the primary peds</td>
</tr>
<tr>
<td>(\sigma)</td>
<td>(\text{Kg}<em>\text{water}/\text{kg}</em>\text{soil})</td>
<td>TC</td>
<td>Skin water at the surface of primary peds</td>
</tr>
<tr>
<td>(K_{ma}^o)</td>
<td>(\text{dm/s})</td>
<td>CC</td>
<td>Hydraulic conductivity at dry point of macroporosity (point C?)</td>
</tr>
<tr>
<td>(K_{maSat})</td>
<td>(\text{dm/s})</td>
<td>CC</td>
<td>Hydraulic conductivity at saturation (point L or F?)</td>
</tr>
<tr>
<td>(\alpha)</td>
<td>(\text{Kg}<em>\text{soil}/\text{kg}</em>\text{water})</td>
<td>CC</td>
<td>Constant of the exponential increase of (K_{ma}) with (W_{ma})</td>
</tr>
<tr>
<td>(E_{mi})</td>
<td>Joules/\text{kg}_\text{soil}</td>
<td>SwC</td>
<td>Potential energy of the internal surfaces of primary peds</td>
</tr>
<tr>
<td>(K_{mi})</td>
<td>(\text{Kg}<em>\text{water}/\text{kg}</em>\text{soil}/\text{KPa}/\text{s})</td>
<td>SwC</td>
<td>Exchange rate coefficient between (W_{mi}) and (W_{ma})</td>
</tr>
</tbody>
</table>

**Notes:**

\(V_D\) might be replaced with \(V_N\) given the transformation file that we are using solves for \(V_D\).

**Model Sensitivity Analysis and Calibration**

As described in the methodology, sensitivity analysis of the fourteen pedostructure parameters will be performed by testing the variability and accuracy of model output as function of parameter fluctuation. Sensitivity analysis will be performed for predefined ranges for the pedostructure parameters. This will eliminate the misleading results that might arise from testing the sensitivity of a parameter that happens to be out of the range of its physical definition.

Model calibration will follow to obtain the pedostructure parameters whose output matches best with the experimental data. This will allow for the evaluation/validation of each soil profile were measure and calculated following infiltration (Nielsen et al., 1964 need to obtain this paper).
the Excel worksheet by comparing the calibrated parameters with those estimated by the worksheet.

**Comments on Data and Model Availability**

Ideally, KAMEL evaluation must be performed on a soil that was analyzed for pedostructure parameterization. However, and in the absence of similar studies, pedostructure parameters were obtained by transforming traditional soil parameters from the literature (Davidson et al., 1969). The complete methodology for parameter measurement and calculation by Davidson et al. (Nielsen et al., 1964) needs to be assessed.

The Excel file that transform the traditional soil parameters to the pedostructure parameters needs to be well documented as no document was obtained that describes the full methodology adopted in transforming the pedostructure parameters.

KAMEL model does not have help documents, and this would result in continuous need for direct interaction with the model developers.

**References**

Experimental data from Literature (Davidson et al., 1969):
Bulk density, h-Θ, K-Θ, and q-t data for the three soils: Yolo loam, Miller silty clay, and Cobb loamy sand.

Data transformation to the complete set of the fourteen pedostructure parameters:
Tool: Excel worksheet.

Simulation of infiltration for simple soil column case using KAMEL model:
Tool: KAMEL. Input parameters: obtained from Excel worksheet (Step 2)

Compare KAMEL output with K-Θ, and q-t data obtained from literature (Davidson et al., 1969):
Model evaluation/ Excel worksheet validation

Sensitivity Analysis of pedostructure parameters (Table 1) and comparison of KAMEL output data from literature (Davidson et al., 1969):
Model sensitivity analysis

Model calibration/ validation:
Test for Model stability and consistency with experimental results.

Figure 1: Flow chart of the methodology