Assessing the impact of a soil surface crust on simulated overland flow at the field scale.

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The problem

• Surface crusts have widely been reported to reduce the infiltration rate of soils.

• Most infiltration models try to represent a crusted soil as a double layer system (Chu et al., 1985; Philip, 1998, Smith et al., 1999).

• However
  
  - the determination of the hydraulic properties of the crust is difficult.
  
  - the integration of a double layer in the overland flow module of a distributed hydrological model can be cumbersome.
The objectives

- Can the impact of a crust be seen on overland flow simulations at the field scale?

- Does the use of a double layer model improve overland flow simulations?
The Methodology

- Use cumulated infiltration experiments to determine crust and sub-soil hydraulic properties by inverse modelling at the local scale (177 cm²).

- Simulate overland flow at the field scale (1200 m_) using previously determined parameters in a single layer and double layer model.

- Compare the results obtained by double layer and single layer representations.
1. The study zone

- Area: 1200 m$^2$
- Soil texture: Silty loam
- Presence of a sedimentary crust
- Vegetation: Vine
- Infiltration capacity: 7.9 mm$h^{-1}$
- High runoff coefficients (23-80 %)
2.1 Infiltration experiments at the local scale

- Two cumulated infiltration experiments with a 14cm cylinder
- Measure $\theta_i$ before experiment and add known volumes of water until steady state.

NB: Measurement is representative of superficial soil layer (0-10 cm) (De Condappa & Soria-Ugalde, 2002)
2.2 Inverse modelling

- Determine soil hydraulic properties using HYDRUS-2D (Simunek et al., 1999) in inverse modelling in axi-symmetric mode.

**Step 1**
- Subsoil
- $K_s, \theta_s, n, \alpha_{\text{subsoil}}$

**Step 2**
- Subsoil
- $K_s, \theta_s, n, \alpha_{\text{crust}}$

**Step 3**
- Crust + subsoil
- $K_s, \theta_s, n, \alpha_{\text{crust+subsoil}}$

(Effective parameters)
2.2 Inverse modelling

722 triangular elements
200 nodes
2.3 Results of inverse modelling: Soil hydraulic properties (Van Genuchten, 1980)

<table>
<thead>
<tr>
<th></th>
<th>( \theta_s ) (cm(^3).cm(^{-3}))</th>
<th>( \alpha ) (mm(^{-1}))</th>
<th>n</th>
<th>( K_s ) (mm.h(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crust</td>
<td>0.39</td>
<td>1.56 (10^{-2})</td>
<td>1.93</td>
<td>2.37</td>
</tr>
<tr>
<td>Subsoil</td>
<td>0.37</td>
<td>2.79 (10^{-2})</td>
<td>3.00</td>
<td>23.98</td>
</tr>
<tr>
<td>Crust+subsoil as homogeneous layer</td>
<td>0.37</td>
<td>4.41 (10^{-2})</td>
<td>3.00</td>
<td>8.56</td>
</tr>
</tbody>
</table>

\( K_s \) subsoil = 10* \( K_s \) crust

\( K_s \) crust+subsoil \( \approx \) harmonic mean (\( K_s \)crust + \( K_s \)subsoil)
3.1 Overland flow simulations at field scale: rainfall/ runoff data

- Experimental data available since 1993
  - 12 events (θi known) and note prone to measurement errors
  - Duration: 30 min-23 hours
  - Runoff coefficient: 27-79%
3.2 The overland flow model

- Simulate overland flow using:
  - 1 D Richards’ equation for infiltration;
  - Diffusive wave model for transfer.

- Two sets of simulations done with previously determined soil hydraulic properties:
  - Using a double layer representation of soil;
  - Using the effective parameters.
3.2 Comparison on double vs. single layer representation on runoff data

Effective parameters tend to underestimate runoff depth.
Double layer model tends to overestimate runoff depth.
3.2 Comparison on double vs. single layer representation on runoff data

Error on Volume using single layer model (%) vs. Error on volume using a double layer model (%)

Error on $Q_{\text{max}}$ using single layer model (%) vs. Error on $Q_{\text{max}}$ using a double layer model (%)

Error double layer model > Error effective parameters
3.2 Comparison on double vs. single layer representation on runoff data

Nash and Sutcliffe efficiency using a double layer model (%) vs. Nash and Sutcliffe efficiency using a single layer model (%)

Nash Effective parameters > Nash double layer model
Model gives good results for short to medium duration events (duration < 10 hours).
3.3 Nash & Sutcliffe efficiency vs. event type using effective parameters

Model gives good results for moderate infiltration depths (depth < 70 cm). Infiltration front too deep h and θ unknown
4. Concluding remarks & perspectives

- The cumulated infiltration test did show that the crust hydraulic properties differ from that of the subsoil.

- The soil hydraulic properties determined at the local scale can be used to simulate overland flow at the field scale provided infiltration front is < measurement domain.

- A refinement at the local scale is not always rewarded by a greater precision at the field scale.

- As overland flow is dependent on rainfall, a misrepresentation of the soil properties may be masked by the rainfall effect.
Thank you!

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3.3 Nash & Sutcliffe efficiency vs. event type using effective parameters

High intensity rainfall events are well simulated.