General Comments:

Abstract

On the basis of the Reviewer's comments we recognize that the abstract is not specific enough, as it describes both geotechnical and hydrological feedbacks in landslide hydrology, and it might lead to wrong impression of the content of the paper.
The aim of our manuscript is to model preferential fissure flow at the hillslope scale with focus on the dynamic hydrological effect of the fissure network. This includes the dynamic fissure connectivity approach in a distributed hydrological model.

We will rewrite the abstract to clarify the actual content of the paper.

Methodology

Many Reviewer's comments are related to misunderstanding of what the model represents and how it is implemented. We see this as an omission from our side. Therefore we take double care to clarify this here and we will include this in the revised manuscript.

The hydrological system considered in this paper is a dual – permeability concept mimicking both matrix and fissure domain. The volume of fissures within one cell is defined by the fraction of surface area covered with fissures (F_{fis}) and the mean fissure aperture (a_{fis}). Fissures are distributed evenly through out the cell (in both x and y direction) and they extend vertically over the full depth of the layer. Moreover, field surveys showed that majority of the fissures are partly (re-) filled with landslide material, so no continuous open fissures. Therefore, in the model, we define that fissures are filled with reworking material and that they retain their own permeability, porosity and soil moisture content.

The model allows defining the fissure fraction and its aperture per cell and per layer. Fissure contents can vary from cell to cell and from layer to layer. The only limitation is that fissures are fully connected vertically, between layers. Additionally, it is possible that fissure will terminate in the first (top) or second layer and not extend to the bottom entirely.

The hydrological components of STARWARS model describe the transient saturated and unsaturated flow as a function of gravitational potential only. As a consequence, percolation (in matrix and fissures domain) is limited to gravitational vertical flow only.

The fluxes within a single soil column consisting of three layers – Figure 1b

The unsaturated fluxes in the matrix or fissure domain (percolation, *Pe*) are controlled by the unsaturated hydraulic conductivity. The soil water retention curve is described by Farrel and Larson (1972):

$$\theta_{E,mat/fis} = 1 - \frac{1}{\alpha_{mat/fis}} \cdot \ln\left(\frac{|h_{mat/fis}|}{h_{A,mat/fis}}\right)$$ Equation 1

where $|h|$ is the absolute matrix suction (m), h_A is the air entry value (m), and □ is the shape factor (-). If $|h|$ is less or equal to h_A the soil remains saturated throughout
The corresponding relationship for the relative unsaturated hydraulic conductivity (k_r (-)) of Millington and Quirk (1959):

$$k_r(\theta_E) = \theta_E^{\tau} \cdot \frac{[\exp(2\cdot\alpha\cdot\theta_E) - 2\cdot\alpha\cdot\theta_E - 1]}{[\exp(2\cdot\alpha) - 2\cdot\alpha - 1]}$$ Equation 2

where τ is the tortuosity parameter and is set to 4/3 (-). This equation is applied to calculate unsaturated hydraulic conductivity of both matrix ($k_{r,mat}$) and fissures ($k_{r,fis}$).

Any water in excess of the storage capacity of the particular layer is passed on to the overlying layer. Any water in excess of the total storage capacity of the matrix within a particular soil column is passed on to saturated storage in the fissure network in this column. When the amount of water exceeds the total available storage capacity of the fissure network within the column, overland flow occurs.

Lateral fluxes within the column are possible only between the saturated zones of matrix and fissure domain ($\Gamma_{Sat,\ FM/MF}$) and between the saturated zone of the fissure domain and the unsaturated zones of the matrix domain ($\Gamma_{Unsat,\ FM}$,). No lateral fluxes occur between the unsaturated zone of fissure network and unsaturated matrix. However, fissures can drain vertically into the soil when they terminate above the lithic contact.

The distribution of fissures in two directions is included to approximate landslide reality (transversal and lateral fissures resulting form stress patterns and differential movements).

The fluxes between the soil columns – Figure 1c

Lateral flow between soil columns (Q_{sat}) occurs within the saturated zone only as result of differences in total piezometric head in the x- and y- direction. The total head in each column is composed of the gravitational potential, the elevation of the bottom of the soil column, and the average of the water level in both fissure network and matrix, weighed by the respective surface area.

It is important to stress, that there is no explicit "fissure to fissure" in adjacent column exchange of groundwater.

The total saturated lateral flux is subsequently distributed over the matrix and fissure domains on basis of the ratio of the transmissivity values within a column and the connectivity between fissures. Transmissivity per domain is the product of saturated permeability (fissure/matrix), water height (in matrix and fissure) and width (matrix width in cell and fissure width in cell).

The fissure connectivity should be seen as a chance for the fissure network to be connected laterally between two soil columns. Basically, this means that the fissure fraction multiplied with the fissure connectivity is redistributed in the fissure system, the remaining part ($1-C_{fis}$) is flowing into the matrix domain.

Fissure connectivity

Here we elaborate on the dynamic nature of the "fissure connectivity". We have made the "fissure connectivity" term (C_{fis}) dependent on the soil moisture content of the soil column. In this way we conceptualize the water exchange between columns (the total saturated lateral flux) as such that the effectiveness of the water flux between soil columns mimicking the flow through the fissure fraction depends on the saturation degree of the soil column. We established a relationship between soil moisture content in the soil column and "fissure connectivity". The threshold relationship is defined for field capacity to complete saturation: the chance for fissures to be connected is minimal (set as 0.10) if the overall saturation is relatively low (soil moisture content in column below field capacity) and maximum (set as 0.9) in case of full saturation. This dynamic fissure behaviour is thus a saturation dependent functional connectivity introduced into the spatially distributed hydrological model of STARWARS.

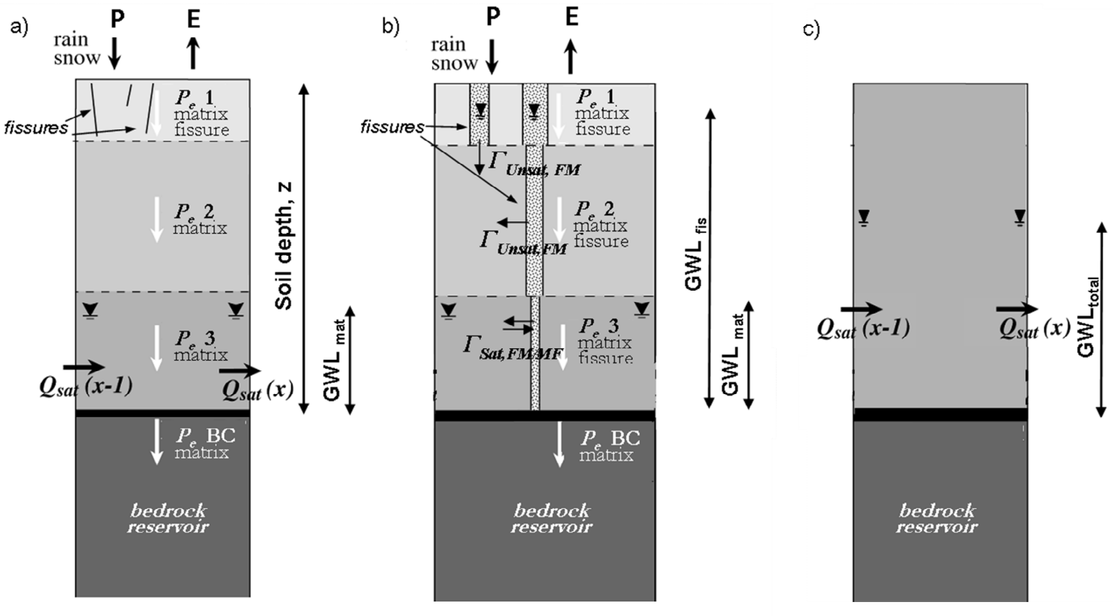

Figure 2. (a) Schematisation of the original hydrological model (Malet et al. 2005, after van Beek, 2002); (b-c) The hydrological model implemented with this research, showing the schematisation and implementation of fluxes within soil column (b) and between the columns (c).