5th Italian Workshop on Landslides (IWL 2018)
28 - 30 May 2018, Napoli, Italy

QUANTIFYING THE HYDROLOGICAL EFFECT OF ROOTS ON SHALLOW LANDSLIDES TRIGGERING USING A 3D HYDROLOGICAL MODEL

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The triggering of shallow landslides in sloped landscape is strongly controlled by the distribution of vegetation. Plants stabilize the hillslope through mechanical and hydrological effects[1]. The former is due to the plant roots that anchor the top soil to the deeper layers and increase the tensile strength of near surface soils[2,3]. The latter is due to: i) the rainfall interception of the foliage system and ii) the root network water uptake/evapotranspiration. This results in higher suction pressure-head values and increases the soil shear strength[4] .
Although several studies in the last decades have focused on the mechanical contribution of root reinforcement[5,6,7,8], only few recent papers have focused on understanding the hydrological effects of vegetation on the slope stability[9,10,11,1]. On one hand, at the hillslope scale the hydrological contribution of roots to the slope stability resulted smaller compared to the mechanical reinforcement. On the other hand, at the catchment scale the hydrological effect of the vegetation tends to become more important. The regulation of water fluxes in saturated/unsaturated soils, the correct simulation of evapotranspiration processes, the heterogeneity of vegetation types play an important role on slope stability at catchment scale, especially when the hydrological system is hit by short intense rainfall[12].
Understanding the combined effects of all these processes on the slope hydrology and stability at the catchment scale is the primary objective of this paper.

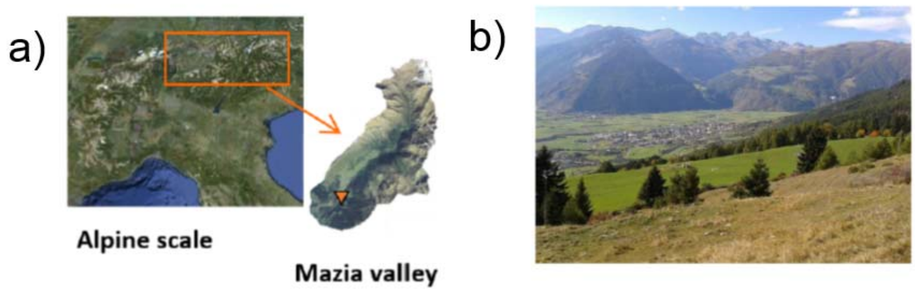

Figure 1: Geomorphological representation of the study area (a) and a picture of the Mazia Valley (BZ)

The study combines long-term field measurement campaigns with advanced numerical simulations in the Mazia Valley (South Tyrol, Northern Italy) (Figure 1). The landscape is very complex from a hydrological perspective due to the strong interaction between the extremely heterogeneous biotic/abiotic system and the high topographic gradient (between 900 and 2200 m a. s. l.) (Figure 2). The latter makes part of the catchment highly susceptible to shallow landslide. We focused our analysis on a 5 km^2 hillslope within the Mazia Valley Long Term (Socio) Ecological Research area (LT(S)ER) (Figure 2). The area includes 2 sites characterized by a continuous monitoring precipitation, wind speed and direction, air temperature and relative humidity, soil moisture at 2-5-20 cm, global radiation, two sites with eddy-covariance evapotranspiration observations, and one site with suction pressure-head data. Moreover, a spatially distributed field campaign for root and soil depth measurements have been carried out over the analyzed h. Finally, distributed and ground and remote sensing observations of surface soil moisture are available over the area for model validation[13].

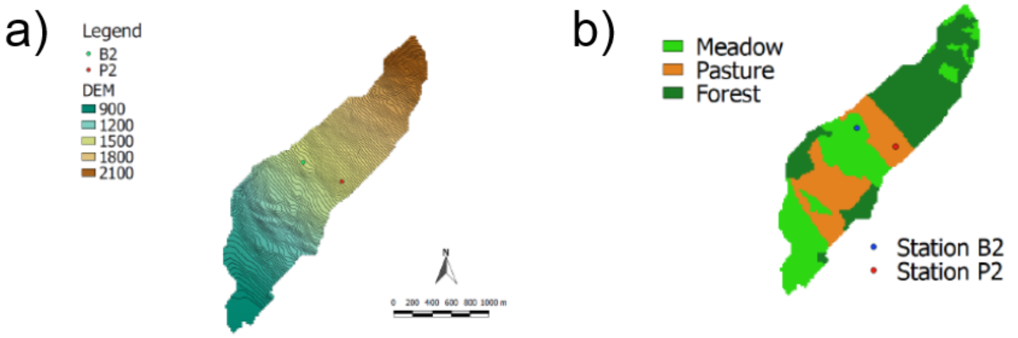

Figure 2: Digital elevation model (a) and landcover (b) of the study area with the location of the two eddy-covariance towers.

Measured data have been used to feed a 3-D, physically based, distributed hydrological model[14,15] coupled with a module for computation of the probability of failure, based on the infinite slope assumption.[16,17,18,19] The model solves the couple Richards and surface energy balance equations (considering soil freezing and vegetation influence) to describe the subsurface flow in variably saturated soils, evapotranspiration, and snow melting. Finally, the stability model simulates the temporal variation of the probability of failure in the study area. Model results in terms of soil moisture/pressure head at different depths have been validated against field measurements and used to estimate the probability of failure within the analyzed catchment. Preliminary results for a 2 years simulation period indicate that the model was able to capture the overall soil moisture dynamics simulated with other well-established integrated models as CATHY [20] and measured in the stations (Figure 3). The simulated spatial soil water content distribution (Figure 4) strongly reflect land covers patterns, which are indeed controlled by the root depth distribution (assumed here 15 cm for meadow areas, 40 cm for pasture and 1 m for forest). The framework allowed us to investigate the combined effect of land cover/use, vegetation types, and freezing soil on soil moisture and suction pressure-head dynamic. Subsequently, we were able to evaluate the relative impacts of the hydrological effects of vegetation on landslide susceptibility. Once the model has been validated, we performed a series of numerical experiments with different vegetation types and root depth and density. Future applications will focus on quantifying the potential effects of climate/land cover changes on the study area.

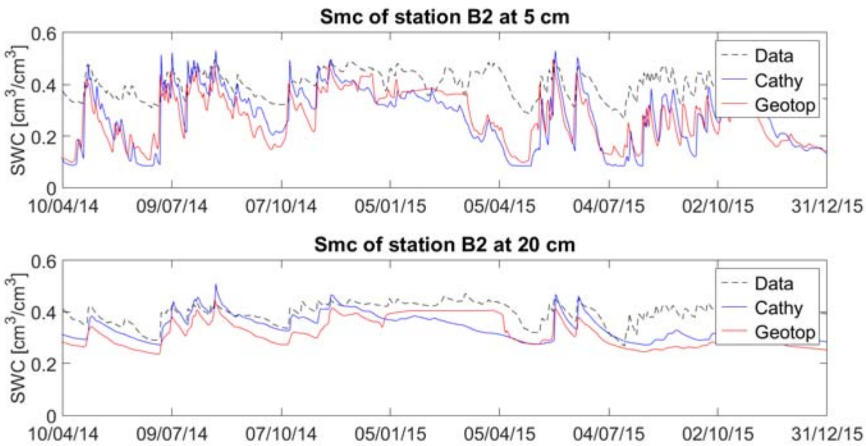

Figure 3: Simulated volumetric soil water content by the GEOtop and Cathy models compared with field observations for the 2014-2015 hydrological year.

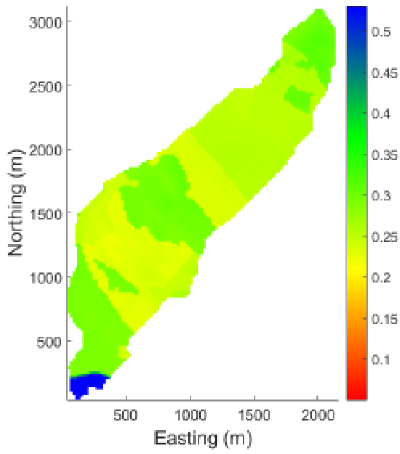

Figure 4: Simulated volumetic soil water content by the GEOtop model over the test area on 23/06/2014.

Keywords: Rainfall induced shallow landslide, unsaturated soils, plants roots

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