The triggering of shallow landslides in sloped landscapes is strongly controlled by the distribution of vegetation. Plants stabilize the hillslope through mechanical and hydrological effects. 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. 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.

Although several studies in the last decades have focused on the mechanical contribution of root reinforcement, only few recent papers have focused on understanding the hydrological effects of vegetation on the slope stability. 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.

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.

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 landslides...
landslide. We focused our analysis on a 5 km² 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 validation13.

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
model14,15 coupled with a module for computation of the probability of failure, based on the
infinite slope assumption16,17,18,19. 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 volumetric soil water content by the GEOtop model over the test area on 23/06/2014.

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

References

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