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Modelling the effect of agricultural practice on soil loss and surface hidrology in Mediterranean clayey hillslopes

Casadei M., Farabegoli E. and Tosi M.

Università degli Studi di Bologna, Dipartimento di Scienze della Terra e Geologico-Ambientali, Italy

(casadei@geomin.unibo.it / Phone: +39-051-2094597)

In the Mediterranean areas, during the latest 50 years, the increasing demand of productive areas combined to the modern mechanized cropping technique has led to the attempt to exploit for agricultural purposes steep to moderately steep(10˚-20˚) clayey hillslopes. In these areas, inadequate cropping and drainage techniques often generates soil loss, mostly in terms of small, shallow soil slips rather than detachment from rainsplash and runoff. The economical losses can be noteworthy, up to 1500 EUR ha^{-1} yr^{-1} for high value cultivations such as vineyards.

We have attempted to estimate the spatial pattern of soil loss susceptibility, by applying Shalstab (e.g. Montgomery and Dietrich, 1994), a physically-based model that calculates the relative shallow landslide potential under steady-state hydrological conditions. This approach assumes the existence of a slope-parallel critical surface that acts as permeability threshold as well as potential failure surface, which is quite reasonable for agricultural plots.

We tested the model on a sample plot area about 30.000 m^2 wide, located near Predappio (Italy) that features two typical conditions in Mediterranean hillslopes: a clay-rich bedrock, and an agricultural practice that creates a well-defined uppermost soil mantle, and controls the spatial distribution of landsliding at least as much as natural topographic control (slope and drainage area).

The detailed topography of the site and the spatial pattern of shallow landslides were collected during a detailed field survey, using a Laserscanning Totalstation (deriving a 5 m grid DEM). A Ground Penetrating Radar survey was carried out to verify the geometry of the subsurface, and the soil hydraulic conductivity (k) was measured in the field with the Guelph permeameter. The soil geotechnical properties (ρ_s, φ' and c') were measured from laboratory tests on selected samples from the field, as well as from *in situ* vane tests.

The spatial distribution of landslide scarps was simulated using Shalstab, and assuming null cohesion at the interface between the topsoil layer, reworked by agricultural practice, and the underlying bedrock. The best run, obtained using ρ_s = 1700 kg/m^3 and φ'= 22°, is unable to discriminate the effect of the surface drainages on shallow landslide potential.

This is a consequence of the fact that, for a given set of geotechnical soil properties, the model expects that the spatial pattern of soil slips is controlled by topography alone, which is not the case in some parts of the study area (as well in many field crop parcels).

We attempted to improve the results by accounting for the modification of surface hydrology due to drainage and other works. The presence of channeled segments such as roads, drainages or ditches generates Hortonian runoff and deviates water from its natural flow paths. For the given area, we used the simple assumption that all the water flowing into an artificial channel segment is transferred to the lower channel pixels, without any leaking to the adjacent hillslope pixels; the flow propagates down to the lowermost channel pixel, where it is delivered to the hillslope.

The simulations run accounting for the modification of drainage area due to the surface drainages yielded more realistic results: the estimated shallow landslide potential turns out to be lower near to the artificial channels, whereas in the areas farther from the drainages, the pattern is reasonably explained by the topographic control

References

Montgomery, D. R., and Dietrich, W. E., A Physically-Based Model for the Topographic Control on Shallow Landsliding, Water Resources Research, v. 30, p. 1153-1171, 1994.