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A distributed model for slope stability analysis using radar detected rainfall intensity

L. Leoni, G. Rossi, and F. Catani

Università degli Studi di Firenze, Dipartimento di Scienze della Terra, Firenze, Italy (lorenzo.leoni@unifi.it)

The term shallow landslides is widely used in literature to describe a slope movement of limited size that mainly develops in soils up to a maximum of a few meters. Shallow landslides are usually triggered by heavy rainfall because, as the water starts to in[U+FB01]ltrate in the soil, the pore-water pressure increases so that the shear strength of the soil is reduced leading to slope failure.

We have developed a distributed hydrological-geotechnical model for the forecasting of the temporal and spatial distribution of shallow landslides to be used as a warning system for civil protection purpose. The model uses radar detected rainfall intensity as the input for the hydrological simulation of the in[U+FB01]ltration. Using the rainfall pattern detected by the radar is in fact possible to dynamically control the redistribution of groundwater pressure associated with transient in[U+FB01]ltration of rain so as to infer the slope stability of the studied area. The model deals with both saturated and unsaturated conditions taking into account the effect of soil suction when the soil is not completely saturated.

Two pilot sites have been chosen to develop and test this model: the Armea basin (Liguria, Italy) and the Ischia Island (Campania, Italy). In recent years several severe rainstorms have occurred in both these areas. In at least two cases these have triggered numerous shallow landslides that have caused victims and damaged roads, buildings and agricultural activities.

In its current stage, the basic basin-scale model applied for predicting the probable location of shallow landslides involves several stand-alone components. The solution suggested by Iverson for the Richards equation is used to estimate the transient groundwater pressure head distribution according to radar detected rainfall intensity. A soil depth prediction scheme and a limit-equilibrium infinite slope stability algorithm are used to calculate the distributed factor of safety (FS) at different depths and to record the lowest value in the final output file. The additional ancillary data required have been collected during fieldwork.

To test the effectiveness of the model, near-real time simulations have been performed in the two test sites using data measured during the past rainfall events: December 2006 for the Armea basin and April 2006 for the Island of Ischia. The landslides triggered by rainfall during these two events were known thanks to the data collected during the [U+FB01]eldwork and to the photointerpretation performed on satellite images. Through the analysis of the factor of safety maps obtained during these simulations, it has been possible to evaluate the behaviour of the model in response to different and complex rainfall patterns. Moreover, the comparison of the results with the new landslide inventory map, has provided a spatial validation of the model for the Armea basin.