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Analysis and modeling of soil slips in the Emilia Romagna Apennine (Northern Italy)

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On 10-11 April 2005 the Emilia Romagna Apennine was affected by an intense rainfall event that triggered dozens of soil slips in the Province of Reggio Emilia.
These phenomena have been widely described in the scientific literature, referring to historical events occurred in many parts of the world. The particular danger of these phenomena is related to their speed of development, with the difficulty of foreseeing their location, but also with the high density of distribution of individual phenomena, whose downhill trajectories have a substantial probability of interfering with urbanized areas.
During the event of April 2005 in the Emilia Romagna Apennine, these shallow landslides mainly occurred on slopes of cultivated lands, often provoking the interruption of roads, heavy damages to the farming activities and economic losses. On the basis of an inventory by aerial photograph interpretation, it was possible to locate 45 sites where soil slips occurred. In the present work the study area is described, considering both geological and climatic aspects. The inducing factors, which are relative to the territory morphology, and the outbreak factors of the triggering mechanism, which are relative to the rainfall conditions, are deeply analyzed.
Once known geometrical features and soil characteristics of the slopes, for each site a physically based triggering model, that has recently developed by the Authors, has been applied by considering the local scale of the phenomenon.
The model allows to take into account dynamically, in a simplified way, the connection between the stability condition of a slope, the characteristics of the soil and rainfall amounts, including also antecedent rainfalls. The model, in fact, is aimed to give an answer to the recent challenge represented by the dynamic use of real-time landslides early warning systems, the basis of which have to be the coupling between rainfall amounts, hydrological model and stability slope models.
The triggering model is based on the limit equilibrium method and considers the hypothesis of infinite slope. The model takes into account the mechanical characteristics of the soil, in condition of partial saturation, and the outflow of underground water. The model allows to calculate the safety factor of a slope versus time on the basis of the previous rainfall amount. The paper contains also a detailed explanation of the choice of the model input data that have been used to carry out the procedure of back analysis for the 45 study sites.
In particular, the slope angle has been evaluated for each site on the basis of the Digital Elevation Model (DEM) information and the thickness of the soil has been determined on the basis of field observations. Colluvial, regolithic and in general Quaternary deposits are the soils involved in the soil slips considered. On the basis of geological map information and according to the Unified Soil Classification System (USCS), the most common types of soil present in the sample sites resulted silty sand, silty clay and sandy silt. The physical properties of these soils, such as porosity and specific weight, and Mohr-Coulomb shear strength parameters, were assumed taking into account the average values of parameters as reported in the scientific literature for the same types of soils. Other specific model parameters that are directly linked with the type of soil, have been consequently assigned on the basis of previous works carried out by the Authors. Moreover, the parameter that describes the discharge capability of the soil, has been assumed as typical permeability value obtained through field measurements by other Authors, for similar kind of soils and conditions.
The results obtained by the application of the model are accurately analyzed and discussed. For each analyzed site, it is shown how the model highlights the instability condition on the real date of the event and the stability condition for the remaining period, under an observation period of 3 years, thus confirming the capability of the model to grasp the triggering mechanism of the analyzed phenomena.