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Regional scale analysis and prediction of shallow landslides induced by rain, occurred in the Emilian Apennines, northern Italy.

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Abstract
Rainfall-induced shallow landslides are widespread over the Italian territory, and they occur after heavy rainfalls or prolonged rainfalls of average intensity. This research study concerns the prediction and analysis at a regional scale of shallow landslides occurred in the Emilian Apennines, northern Italy, between 2007 and 2009. As regards the predisposing factors, the problem of rainwater infiltration and the triggering mechanism this kind of slope instability has been widely described in the past. The physically-based model called SLIP (Shallow Landslide Instability Prediction), which has been recently introduced, has been applied on regional scale. The SLIP model is based on the limit equilibrium method and takes into account even previous rainfall. Analysis of the contribution of rainfalls occurred before the landslide triggering instant show that only the 30 days prior the triggering instant affect the safety factor. On the basis of selected case histories and starting from measured rainfalls, the grid method is used to define rainfall maps. Among the model input GIS data, seasonally constant values of the degree of saturation of the soil are used. For the implementation of the model at a regional scale an overview of the study area is given by the warning areas. Time-varying warning areas' safety factor maps, corresponding to different 12-hour steps prior the triggering instant, are produced. From these maps it is possible to observe how the SLIP model works well with respect to the time variable, forecasting instability at the instant in which landslides really occurred. Using the basic parameters of the ROC (Receiver Operating Characteristic) analysis, sensitivity, specificity and overall accuracy of model results can be calculated and a qualitative assessment of the spatial prediction ability of the model can be obtained. In the majority of the analyzed events, the accuracy of the model results good or sufficient. The main reasons that prevent the model from obtaining excellent results are discussed. At first, the inventory database of occurred landslides has many technical problems; secondly, a low resolution (20m) Digital Elevation Model (DEM) is used. Model results are also affected by a poor resolution of the rainfall maps and by an overall lack of spatial accuracy in the geotechnical input data.
Notwithstanding these limits, the SLIP model can be considered, in general, useful for a preliminary estimation of slope stability over large areas, but can not provide the same estimation on specific areas, with the exception of its application on a local scale, where a greater detail of input data is available. Considering the factors limiting the accuracy of the modeling, the results of the SLIP model could be used to define different levels of susceptibility in dynamic terms. In addition, if coupled with a rainfall forecasting model, SLIP could be developed to be used as a warning system against shallow landslides.

Keywords: shallow landslide, GIS, triggering model, safety factor, rainfall.