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Using geotypes for landslide hazard assessment and mapping: a coupled field and GIS-based method

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Switzerland is exceptionally subjected to landslides; indeed, about 10% of its area is considered as unstable. Making this observation, its Department of the Environment (BAFU) introduces in 1997 a method to realize landslide hazard maps. It is routinely used but, like most of the methods applied in Europe to map unstable areas, it is mainly based on the signs of previous or current phenomena (geomorphologic mapping, archive consultation, etc.) even though instabilities can appear where there is nothing to show that they existed earlier. Furthermore, the transcription from the geomorphologic map to the hazard map can vary according to the geologist or the geographer who realizes it: this method is affected by a certain lack of transparency.
The aim of this project is to introduce the bedrock of a new method for landslide hazard mapping; based on instability predisposition assessment, it involves the designation of main factors for landslide susceptibility, their integration in a GIS to calculate a landslide predisposition index and the implementation of new methods to evaluate these factors; to be competitive, these processes have to be both cheap and quick.
To identify the most important parameters to consider for assessing slope stability, we chose a large panel of topographic, geomechanic and hydraulic parameters and tested their importance by calculating safety factors on theoretical landslides using Geostudio 2007®; thus, we could determine that slope, cohesion, hydraulic conductivity and saturation play an important role in soil stability. After showing that cohesion and hydraulic conductivity of loose materials are strongly linked to their granulometry and plasticity index, we implemented two new field tests, one based on teledetection and one coupled sedimentometric and blue methylen test to evaluate these parameters. From these data, we could deduce approximated values of maximum cohesion and saturated hydraulic conductivity. The hydraulic conductivity of fractured rocks was obtained from the analysis of their geometrical properties (fractures density, aperture size and orientation). The other factors were extracted from DEM and hydrologic mapping.
Then, we merged these parameters into three groups corresponding to three families of factors (gravitational, hydrodynamic I based on hydraulic conductivity contrast between superficial loose material and hard rock substratum and hydrodynamic II related to susceptibility to suffosion). We added a fourth factor related to the predisposition of the geotype (new classification for geologic formations, based on genetic standards for loose material and on lithologic standards for hard rock) to slope instability processes: the latter enabled us to integrate attributes proper to each geotypes (over-consolidation for ground moraines, stratifications for glaciolacustrine deposits, etc...) and which would be long and complex to integrate to a GIS.
Afterward, we implemented an ArcGis® toolbox allowing to obtain automatically cohesion, hydraulic conductivity, saturation and slope from field parameters (granulometry, plasticity, fracturation, geomorphology and drainage) and DEM and to calculate geotype, gravitational, hydrodynamic I and hydrodynamic II factors; combining them, we led to a landslide susceptibility index. To know the relative importance of these four factors, we tried different weightings on four areas in different geologic contexts of Switzerland (flysch, molasse, crystallin) and of different sizes (from 0.1 to 2.5 km2).
Finally, we applied this methodology (from field survey to GIS operations) to five other sites in Switzerland to check its validity: in flysch and molassic contexts, more than 90% of actual landslides were classified as “very susceptible to slope instability”. In Triassic area, more than 50% of the actual unstable areas were classified as "stable", which is not satisfying:in this case, it should be necessary to integrate another layer of data to take into account dissolution and plasticity of Triassic formations.
The main assets of this new method are that the integration of field measurements in GIS provides for a good

transparency in the landslide susceptibility index attribution and that the use of geotypes classification enables to use this method in most of European contexts.