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Topographic units mapping from DEM analysis: evaluation of the Upslope Position Index (UPI) in two Tuscany (Italy) study areas

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Abstract: The Earth's surface is structured into landforms as the result of the spatial distribution and redistribution of materials and energy in the landscape. The study of landforms is used to make further inferences pertaining to expected site conditions such as kind and degree of pedogenesis, texture and stability of unconsolidated sediments (R.A. MacMIllan and P.A. Shary).
Moreover the study of landforms can be applied to the evaluation of natural hazard, particularly for relationships between runoff and shallow slope stability.
This paper presents a new index obtained from Digital Elevation Model (DEM) as input datum, the Upslope Position Index (UPI), aimed at classification of topographic units, this latter being in turn necessary data for landforms analysis. The results of application of the UPI are compared to the Jenness' Slope Position Index and to the expert knowledge resulting from geomorphologic visual interpretation of aerial photos.
The study areas are two catchments in Italy (Sieve river and Serchio river watersheds, Tuscany) where a DEM with a cell size of 10 m was used as input.
The two above terrain analysis methodologies are based on different underlying principles, namely: the flow length accumulation and the spatial analysis of topographic parameters.
The UPI method is based on the use of the flow length GIS function in order to calculate the downstream and upstream weighted distance along a flow path from each cell to, respectively, either the valley bottom or the watershed divide. By calculating of the upstream flow length normalized in respect to the flow path, we obtained the UPI. The UPI allows us to make comparisons among catchments with different size and geographic locations.
The second methodology is based on two indexes derived from DEM, namely the Topographic Position Index (TPI), and Slope Position Index (SPI). These indexes are processed in order to differentiate among geomorphological units expressing whether the elevation of a given cell is higher or lower than the mean elevation of its neighbors. Topographic categories based on these indexes are represented by ridges, upper slopes, middle slopes, lower slopes, valleys and flat areas.
The cross-method and absolute accuracy assessments were performed. For each study area a random sampling scheme was used. The values of SPI and UPI to be assessed were automatically extracted from the output topographic units maps. The ground truth data were defined by means of an expert geomorphologic visual interpretation of aerial photos.
The analysis of three confusion matrices, the cross-method matrix and the comparison between each single method and the ground truth, shows good accuracy (agreement) of the results.
The authors believe the UPI approach explored in this study might be one of the first steps in a logical process aimed at evaluating natural hazard related to shallow slope instability processes.