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Identification and prediction of channel heads from gridded elevation data

Stefano Orlandini (1), Giovanni Moretti (1), Paolo Tarolli (2), and Giancarlo Dalla Fontana (2)

(1) Department of Mechanical & Civil Engineering, University of Modena & Reggio Emilia, Modena, Italy (stefano.orlandini@unimore.it, giovanni.moretti@unimore.it), (2) Department of Land and Agroforest Environments, University of Padua, Padua, Italy (paolo.tarolli@unipd.it, giancarlo.dallafontana@unipd.it)

The representation and prediction of stream channels in drainage basins has been a perennial concern in geomorphology, with implications for understanding of drainage basin origin, scale and morphology, basin hydrology, and effects of natural and man-induced process changes. The channel (or stream) network is defined by channels with well-defined banks and sources. In theory, the channel network includes all the minor rills which are definite watercourses, even including all the ephemeral channels in the furthermost headwaters. In practice, the direct survey of all channels is normally a prohibitive task, and the detail with which the channel network is represented is dependent on the scale of the map used to trace the channels. In actual fact, the headward limits of the blue lines do not reflect any statistical characteristic of streamflow occurrence, but they are drawn to fit a rather personalized aesthetic. On the other hand, the explicit description of the mechanisms determining the channel heads is a nontrivial task since it requires complex fluvial and/or landsliding processes to be considered singly or in combination. However, the increasing availability of highly accurate digital elevation data derived from LiDAR surveys, reliable terrain analysis methods, and observations collected in the field or remotely, offers new potential for developing and/or evaluating prediction models for channel initiation. In addition to detailed models, simpler generalizations from field facts can be sought by incorporating the broad features of climate, topography, and geology. In the present study, three threshold conditions for channel initiation are evaluated by using gridded elevation data derived from high-precision LiDAR surveys, a reliable algorithm for the determination of surface flow paths, and accurate field observations of channel heads for sites located in the eastern Italian Alps. These three threshold conditions are determined by considering part of the observed channel heads and computing for them the related values of (1) the drainage area A, (2) the monomial function AS^2 of the drainage area A and the local slope S, and (3) the Strahler order ω^* of surface flow paths extracted from gridded elevation data. Attention is focused on the dependence of the obtained threshold values on the size of grid cells involved, and on the ability of threshold conditions to reproduce the observed channel heads. The results indicate that (i) the uncertainty in the threshold values of the Strahler order ω^* is significantly smaller than that affecting the threshold values of the drainage area A and the area-slope function AS^2, (ii) threshold values of A, AS^2, and ω^* are all significantly dependent on grid cell size, and (iii) the threshold values of the Strahler order ω^* follow quite well a power function relationship of grid cell size. The comparison between reproduced and observed channel networks for several drainage basins indicates that Strahler classification of surface flow paths and pruning of exterior links provides a sound rationale for the determination of channel heads formed essentially by surface erosion, but it reveals that more comprehensive methods are needed to reproduce channel heads in areas affected by strong geologic controls and groundwater seeping upwards.