# Identification of rock-fall hazard at Little Mill Campground (Uinta National Forest, Utah, USA) by DEM analysis.

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The Little Mill Campground lies on the bottom of the deeply incised American Fork Canyon and is surrounded by high cliffs made of dolomite and limestone. Rock-fall activity is quite well known in the study area. Since the 1990ies the rock-fall events are inventoried. Potential rock instabilities were identified and a preliminary hazard assessment shows that most campsites are downslope from areas with moderate to very high rock-fall susceptibility (Coe et al. 2005).
This study aims to identify large slope instabilities around the Little Mill Campground (Uinta National Forest, Utah, USA) site by means of analysis of digital elevation models (DEM). The developed approach allows to determine the rock-fall susceptibility for each DEM cell and thus to detect slope instabilities and their propagation zones at various scales.
Slope instabilities are caused by several factors. Some of them are purely geometric and can be assessed using a DEM (Baillifard et al. 2003, Derron et al. 2005). In this study, we used an 8.85 m DEM available from the National Elevation Dataset of the USGS to evaluate the following rock-fall hazard criteria:

- steepness of topography,
- discontinuities that may cause planar and/or wedge sliding,
- denudation potential of individual rock masses, and
- runout zones of rock-falls.

The histogram of the dip angle derived from the DEM cells can be simulated by four Gaussian distributions. These correspond to the bottom of the valley (mean slope angle 12°), scree slopes (23°), flanks of the valley (39°), and the cliffs (51°) where rock-falls initiate.
A structural and morphological analysis of the DEM with the software COLTOP3D permits the identification of major rock discontinuities which are shaping the relief in American Fork Canyon. Four sets of discontinuities with mean orientations of 060/50 (dip direction/dip angle), 180/55, 240/40, and 300/55 are identified. The software MATTEROCKING is used to map the intersection of these discontinuities with the topography, and gives susceptibility for planar or wedge sliding at each DEM cell based on the apparent density of intersections (Rouiller et al. 1998).
To determine the denudation potential of rock masses in the study area, the sloping local base level (SLBL) concept was used (Jaboyedoff 2004). It defines a basal surface of erosion above which rocks are considered to be susceptible to erosion by mass wasting within a short period of time (i.e. 20'000 years). Zones with high residuals, i.e. large differences in altitudes between the SLBL and the DEM, are susceptible to a higher level of mass wasting activity. Stated in another way, rock-fall susceptibility increases with the residual.
The combination of these three criteria allows for the determination of the overall rock-fall susceptibility for each DEM cell (Figure 1). The shadow-angle method (cone method) is used to determine the runout zones of rock-falls initiating from the

identified susceptible areas (Figure 1). Results show good correspondence with the field observations made by the USGS. Our hazardous areas are more extensive than the observed ones because the shadow-angle method is conservative and provides maximum rock-fall runout zones.

This paper shows that DEM analysis is a very useful tool for preliminary rock-fall hazard assessment because it provides rapid delineation of susceptible areas and runout zones that can be used to supplement or focus detailed field investigations.

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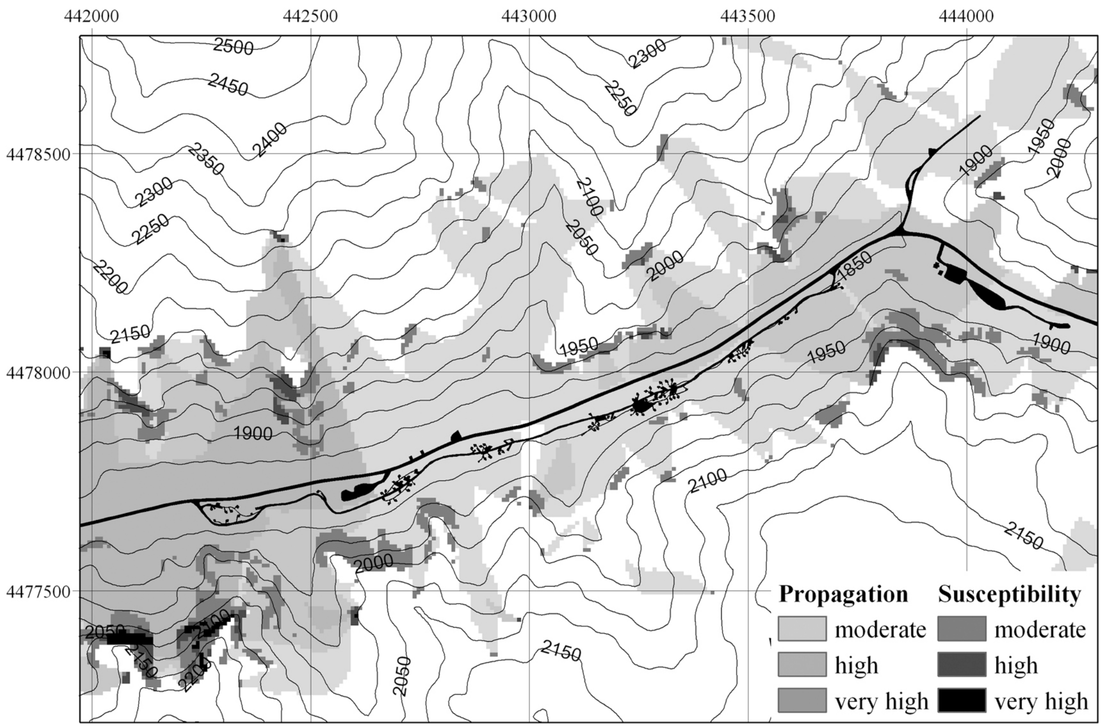


Figure 1. Propagation zones of rock-fall initiating in DEM cells with moderate, high or very high rock-fall susceptibility using the cone method with a shadow angle of 35°. The Highway 92 and the buildings of the Little Mill Campground (taken from Coe et al. 2005) are objects at risk.