Gis - based hazard analysis of torrents and debris flows in Walgau (Vorarlberg/Austria)

E.Nolte[1], **Prof.Dr.K.Czurda**[2]

Geophysical Institute, University of Karlsruhe / contact: Eike.Nolte@gpi.uni-karlsruhe.de

Introduction

In the context of the project "Georisikokarte Vorarlberg" a GIS-based model was developed with respect to hazardous torrents and debris flows. The study area (ca. 40 km^2) is situated in the Walgau near the town Bludenz (Vorarlberg/Austria). The main object was to generate a hazard map, providing an insight into the local exposure of this area due to debris flows. In summer 2005 the geotechnical and geological mapping was carried out. From a geological view the study area lies in the Northern Calcareous Alps (NCA) and the Vorarlberger Flyschzone. Quartenary sediments are widely spread in the Walgau.

GIS - Analysis

The modelizing and the analysis were carried out using a Geographic Informationsystem. All models were programmed with AML within ArcInfo 9.1 to ensure flexible application. All data were analyzed as grids with a cell size of 10 meters. The modelling process was divided into three sub models: disposition model, trajectories model and vulnerability model.

Disposition model

Geological, morphological, climatical and infrastructural data were factored into this part of the analysis and weighted according to their relevance triggering debris flows. The bed load potential of the torrents was calculated according to the *bed load relevant surfaces* approach (Heinimann et al. 1998) (s. Fig. 1). The calculated bed load potential was classified using a Jenks - Algorithm. Five bed load potential classes were obtained ranging from very low to very high (s. Fig. 2). Afterwards the torrents were accounted as capable of debris flows according to the "Grenzgefälle Methode" (Takahashi 1981, Zimmermann et al. 1997). The results were displayed on maps to provide a spatial overview (s. Fig. 3).
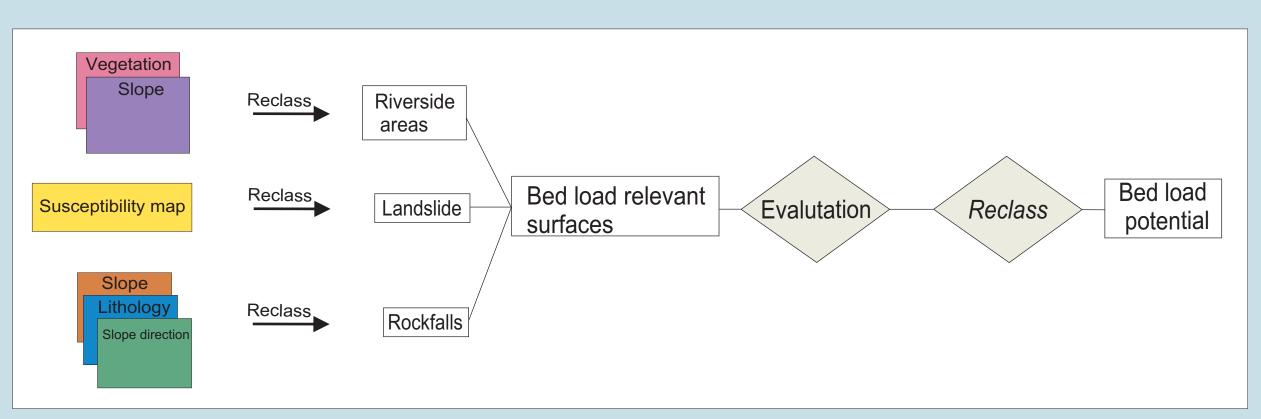

Fig.1: Flow chart showing the data layers used in the bed load potential analysis.

Grenzgefälle Methode

This method is based on the assumption that the critical slope for triggering a debris flow is 27 % (Takahashi 1981). The critical slope **J** was calculated using the empirical formula after Zimmermann et al. (1997). The catchment area **a** for each torrent was calculated using a singleflow direction approach.

$$J = 0,32 * a^{-0,2}$$

Afterwards the slope of each torrent was compared to the critical slope. In case the slope exceeded the critical slope the sufficiency of mobil material was checked using 5000 m^2 of bed load relevant surface as a threshold. The cells, which fulfilled both criteria, were marked as potential starting points for debris flows (s. Fig. 3).
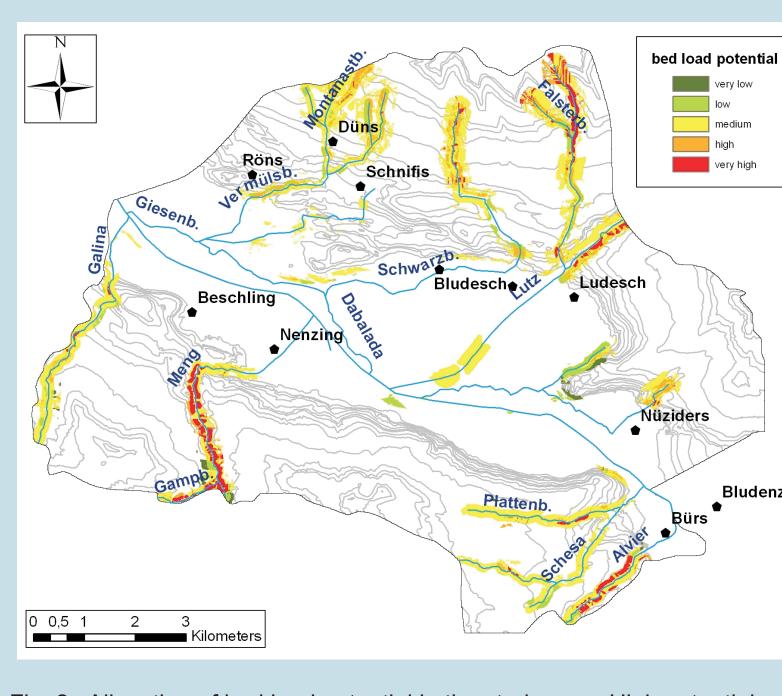

Fig. 2: Allocation of bed load potential in the study area. High potential (redish color) is mainly concentrated along the Meng river in the south of Nenzing and along the Falster torrent.
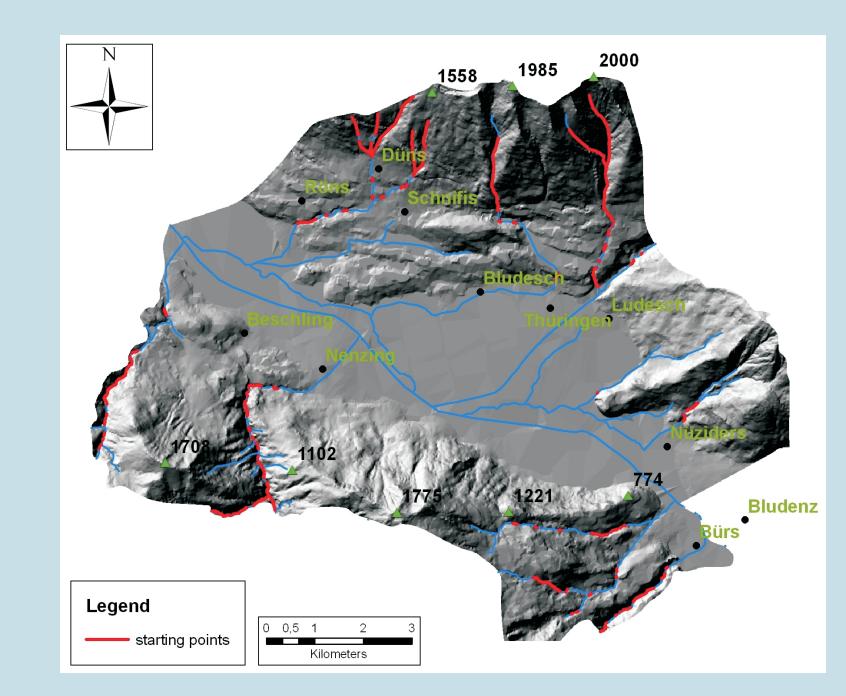

Fig. 3: Potenial starting point in the study area along the stream network. Most of the starting points lie within areas of high altitudes. The highest crests in the study area are marked on the map.

[1] University of Karlsruhe
Geophysical Institute
Hertz Str. 16
76187 Karlsruhe

[2] University of Karlsruhe
Department of Applied Geology
Kaiser Str. 12
76128 Karlsruhe

Literature:
Heinimann et al. (1998): Methoden zur Analyse und Bewertung von Naturgefahren.
Umwelt - Materialien Nr. 85, Naturgefahren. Bundesamt für Umwelt, Wald und Landschaft (BUWAL), Bern.
Takahashi T. (1981): Estimation of potential debris flows and their hazardous zones: soft countermeasures for a disaster .- In: Journal of Natural Disaster Science (3) 1, 57 - 89 S.
Zimmermann et al. (1997): Murganggefahr und Klimaänderung - ein GIS - basierter Ansatz. Vdf. Hochschulverlag Zürich.

Trajectories model

The major aim of this model was the assessment of paths and spreading areas of potential debris flows. Assuming that the energy needed by a debris flow moving downhill is mainly depending on the surface and on the slope of the torrent. Therefore a cost-grid was developed with respect to vegetation, slope and sliding friction. The costs for crossing one cell of the grid depends on the cell characteristics e.g. the higher the sliding friction of a cell the higher the costs for a debris flow to cross it. The factors were weighted according to their influence on the behaviour of potential debris flows. For each possible paths the costs were calculated. The cheapest path was assumed to be the most likely one, whereas the cheapest path does not have to be necessarily the shortest path (s. Fig. 4). The calculated paths were displayed on a hillshade in order to obtain a better spatial visualisation (s. Fig. 5).
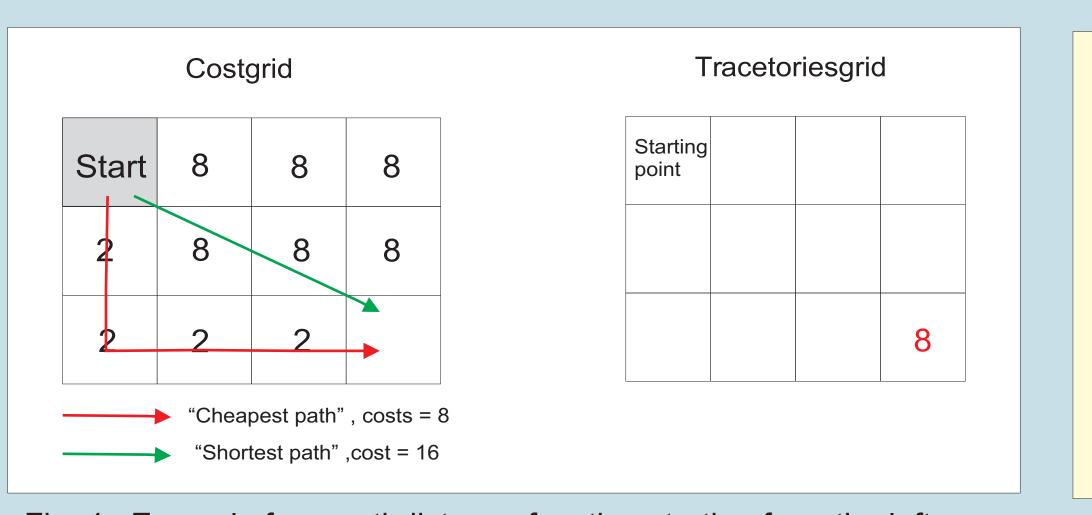

Fig. 4: Example for a pathdistance function starting from the left, upper cell. This function was used to add all costs of a paths and to determine the cheapest path from the costgrid.
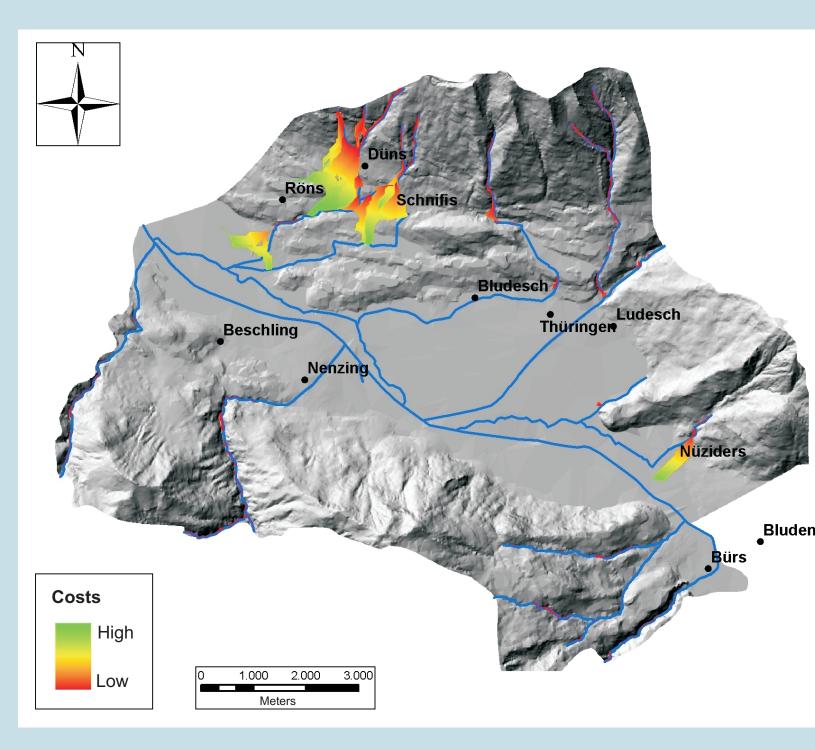

Fig. 5: Trajectories of potential debris flows displayed on a hillshade of the study area. All coloured cell can be possibly reached by debris flows. The costs for crossing the cells are increasing with the distance from the starting point.

Vulnerability model

The vulnerability model was developed to assess the hazard for objects such as building and infrastructure due to debris flows. Only objects within spreading areas, previously comprised in the tracjetories model, were considered. In the analysis simplifying assumptions were made: the hazard is decreasing with distance from the starting point, the higher the costs of a cell the higher the hazard of the object within this cell. The hazard was classified using a Jenks - algorithm. Furthermore the surface percentage of each kind of objects was calculated, whereas residental areas, forest trails and high ways were distinguished.
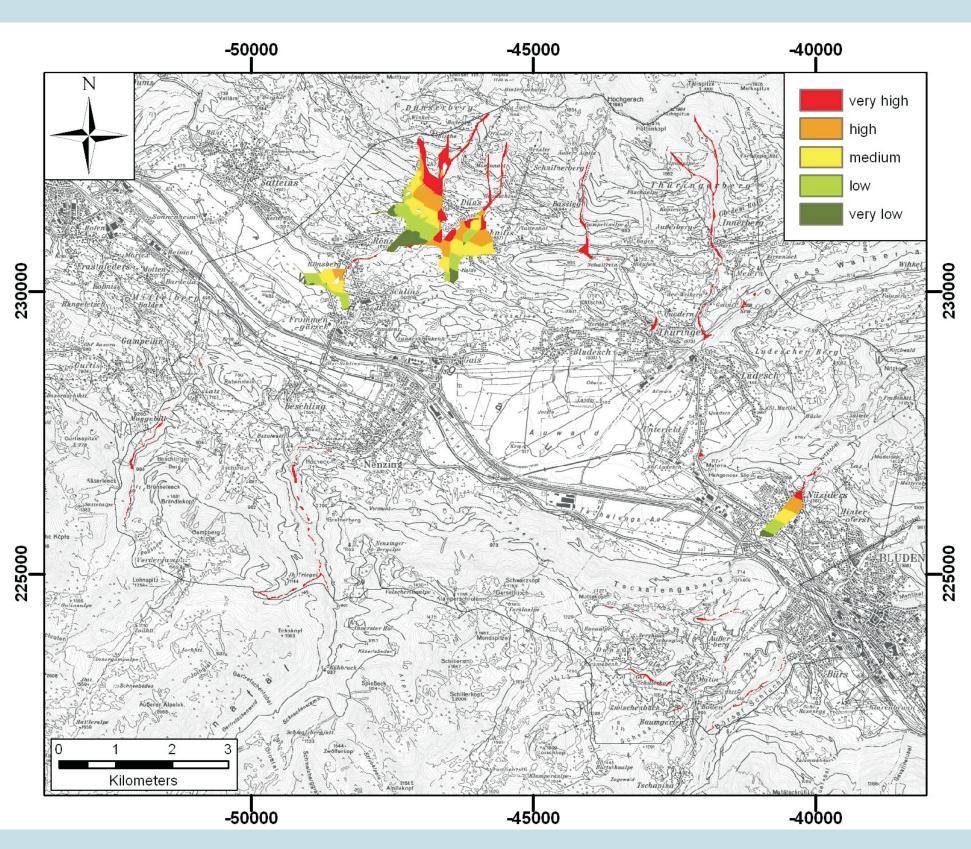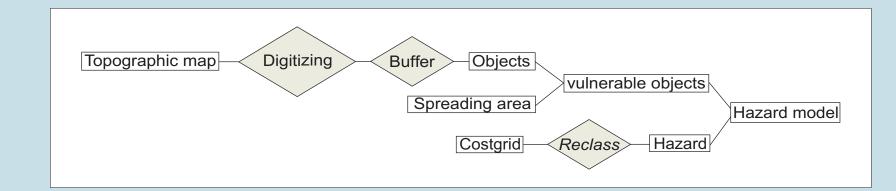

Fig. 6: Flow chart showing the development of the hazard model showing the single modelizing steps.
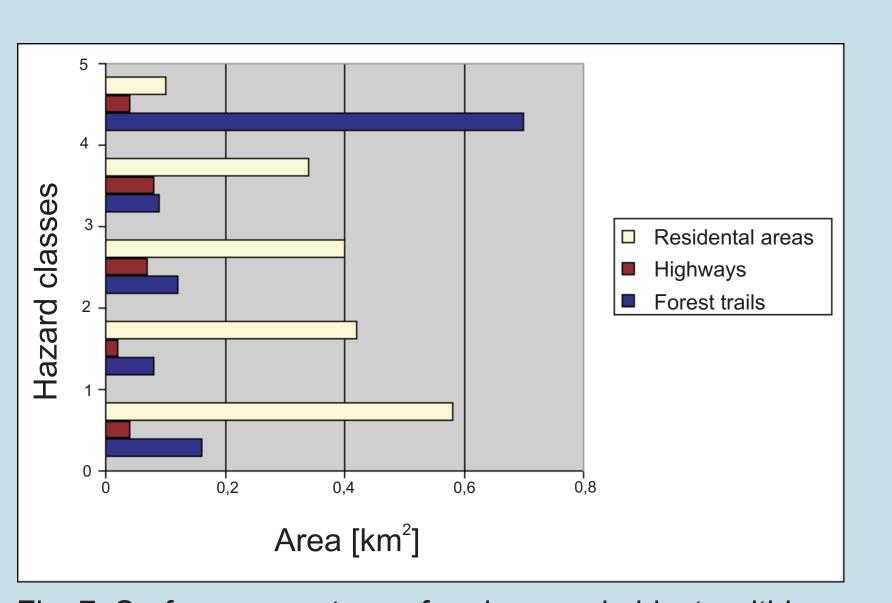
Fig. 7: Surface percentage of endangered objects within the hazard classes.

Fig. 8: Hazard map of the study area. The distribution of the hazard classes with the spreading area is displayed in terms of different colors.

Conclusion

The disposition model was able to acquire most of the bed load relevant surface. The calculated starting points are mainly situated in the northern part of the Walgau. This is due to the high relief of the torrents. In steep torrents calculations e.g. flowdirection are more distinct than in plain torrents. The same applies to the calculated spreading areas. For the northern torrents realistic modelizing was possible. In the southern part of the area the spreading areas could not be modeled. The models developed can be used for a qualitative estimation. A major advantage is that the data required can be quickly assessed and the models can be easily adapted to changing conditions.