HAZARD ASSESSMENT OF LANDSLIDES BASED ON COMPREHENSIVE DOCUMENTATION – ANALYSES AND EXPERIENCES OF THE EVENT IN GASEN AND HASLAU 2005 (AUSTRIA)[1]

HAGEN KARL[*], *ANDRECS PETER*[**]

Key words: landslide, torrent events, hazard assessment, hazard zoning, disaster prevention, Austrian Alps.

Abschätzung der Rutschungsnaturgefahr auf Grund einer umfassenden Dokumentation - Analysen und Erfahrungen für die Ereignisse in Gasen und Haslau 2005 (Österreich). Das wachsende Sicherheitsbedürfnis und der zunehmende Bedarf an nutzbaren Flächen in gebirgigen Regionen erfordern verbesserte Methoden zur Abschätzung von Naturgefahren. Besonders die Gefährdung durch Massenbewegungen bedarf einer Weiterentwicklung der Beurteilungsmethoden, um Gefahrenzonen bestimmen zu können. Basierend auf der umfassenden Dokumentation eines Schadensereignisses in Südost-Österreich, wurde eine Datenbank aufgebaut, die als Basis für die Entwicklung von Methoden zur flächendeckenden Gefahrenzonierung für Rutschungen dienen soll.

Rückschlüsse hinsichtlich der Dokumentationsmethodik werden gegeben sowie Erkenntnisse der Eignung unterschiedlicher Datensätze für die Gefahrenanalyse und -beurteilung vorgestellt, wie zum Beispiel das neue, wetterradarbasierte Vorhersagemodel (INCA), das die Abschätzung der zeitlichen und räumlichen Niederschlagsverteilung ermöglicht, oder die digitale landwirtschaftliche Bodenkarte (EBod) mit rutschungsrelevanten Bodeninformationen. Die Bedeutung verschiedener Datengrundlagen und Parameter für die Bestimmung von durch Rutschungen gefährdeter Bereiche wird diskutiert.

1. INTRODUCTION

Growing concern about public safety, booming tourist areas and insecure further climatic conditions in the Alps require the development and improvement of methods to estimate present and potential natural alpine hazards.

A main preventing measure is to keep endangered areas free from settlement. In this context, the Austrian Federal Service for Torrent and Avalanche Control (WLV) has identified hazards in the so-called hazard-zone maps (GZP) starting in the early 1970s. Nowadays, Austrian land use planning refers to these expertises with legally-binding land use plans. While hazard zoning of floods, debris flows or avalanches is available in particular spatial plans, an urgent need for development remains concerning zoning mass movement hazards. The information about mass movements provided within the presently existing hazard zoning maps is often of a more general nature. There is no statutory commitment to identify landslide zones, for instance. In fact, these are often not marked on the maps and cannot be identified for spatial planning disaster prevention.

---

[1] Paper presented at the IAG Regional Conference on Geomorphology *Landslides, Floods and Global Environmental Change in Mountain Regions*, Braşov, September 15–26, 2008.

[*] Dipl. Eng., Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW), Department of Natural Hazards and Timberline, Hauptstr. 7, 1140 Vienna – Austria, Email: karl.hagen@bfw.gv.at

[**] Dipl. Eng., Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW), Department of Natural Hazards and Timberline, Hauptstr. 7, 1140 Vienna – Austria, Email: peter.andrecs@bfw.gv.at

2. DEFINITIONS

Landslides are sliding movements of loose material along existing slide zones, or occurring at the moment of slope failure arising. The material displacement is caused primarily by gravitation (Schwab *et al.*, 2005). Beside conventional classifications into translational and rotational landslides, a differentiation can roughly be made between:

- spontaneous, more ore less shallow landslides in loose material (Fig. 2a) and
- continuous, often deep-seated mass movements (Fig. 2b)

This classification is adequate in issues of hazard assessment (Table 1). The present paper focuses on the assessment of spontaneous landslides in loose material.

Fig. 1- Building badly affected by a landslide developing into a debris flow (Gasen, 2005). No information was available on landslide hazards in this area (neither any documentation from previous events nor from hazard mapping) although it is very likely (according to oral information and geomorphologic conditions), that landslide events had existed before.

Fig. 2a – Spontaneous, shallow landslides in loose material, partially developing into debris flow (e.g. the Gasen-Austria 2005 event).

Fig 2b – Continuous, deep seated mass movement in bedrock at varying movement rates (e.g. Gradenbach-Austria).

Table 1

A hazard assessment-related, basic classification of landslides and specific values attached.
(*Mass movement – velocity classification by Cruden and Varnes (1996)).

landslide types	**spontaneous**	**continuous**
occurrence	small, varying, large affected area	large, few, limited area
velocity	fast – very fast (extremely fast)*	very slow – slow *
hazards	movement, debris flow	movement, (river load)
documentation	sporadic	+/- well doc.(measurements)
problems	unknown location	movement rates
measures	target measures, slope drainage, etc.	early warning systems, technical limits

Different types of landside processes involve different hazard assessment challenges (compare also Table 1). The following issues are crucial:

- Where will the landslides occur? Continuous (often large) landslides are often known and more or less documented, while comprehensive investigations to determine slope susceptibility (position of potential landslides) is basic to any further actions in this regard.
- What is the probability (frequency) of landslide occurrence (susceptibility – hazard index maps).
- Which area is affected? Spontaneous landslides often develop into debris flow, whereby the affected area is clearly larger than the sliding area.
- What magnitude (volume) will the landslides reach, considering the range and occurrence forces.
- What kind of hazards will occur, in what way will people and their properties be endangered. This depends on the kind of process and more especially on its velocity (hazard assessment).

3. THE GASEN 2005 EVENT (AUSTRIA)

Between the 20th and the 22nd of August 2005, an extreme precipitation event, producing about 200 mm of rainfall within 36 hours (> 100 years return period), triggered off several shallow landslides and mudflows. As an additional triggering factor, a high soil moisture content acting as a critical pre-condition was being considered. The conjunction of these adverse climatic conditions is very rare (return period of >> 100 years, Andrecs *et al.*, 2007).

Basic landslide susceptibility in the area is high because of the absence of glaciation during the last Ice Age, so thick soil and loose material horizons could develop. The area shows a distinct topography with steep slopes and narrow valleys.

The variable susceptibility for spontaneous landslides may be considered high because of extensive forest road construction. About 2/3 of the surveyed landslides were triggered (or increased in magnitude) because of improper road slopes. Agricultural areas were affected more seriously by landslides than forest areas although these areas are found mainly in the steeper parts of the region. When affected, the wooden debris often caused problems by impairing protection measures and jamming channels.

The 2005 event was the starting point for a national landslides standardized documentation. In this connection, the BFW was charged by the Austrian Ministry for Agriculture, Forestry, Environment and Water Management (BMLFUW) to make a detailed investigation of disaster in the most affected areas of Styria (the communities of Gasen and Haslau near Birkfeld (BMLFUW 2006), and so about 250 single landslides were recorded in detail (Andrecs *et al.*, 2007). Also other institutions surveyed the area, and the data collected where included into a collective database (Koicu & Tilch 2005). This database represents the initial point for further analyses and investigations which are supposed to end up in a standardized hazard mapping method of landslides.

3.1 Meteorological survey

There are two sources of obtaining meteorological data:

- Gauging stations and
- Radar-based precipitation data (INCA)

Due to the fact, that there are no meteorological gauging stations located within the affected area (Fig. 3), the precipitation data had to be extrapolated from surrounding measuring points (Hydrographischer Landesdienst, 2005). Because the distribution of precipitation sums at a small scale, especially the precipitation maximum between Gasen and Haslau, is not recorded in this data base, the concentration of landslides in this area cannot be explained on the basis of these data.

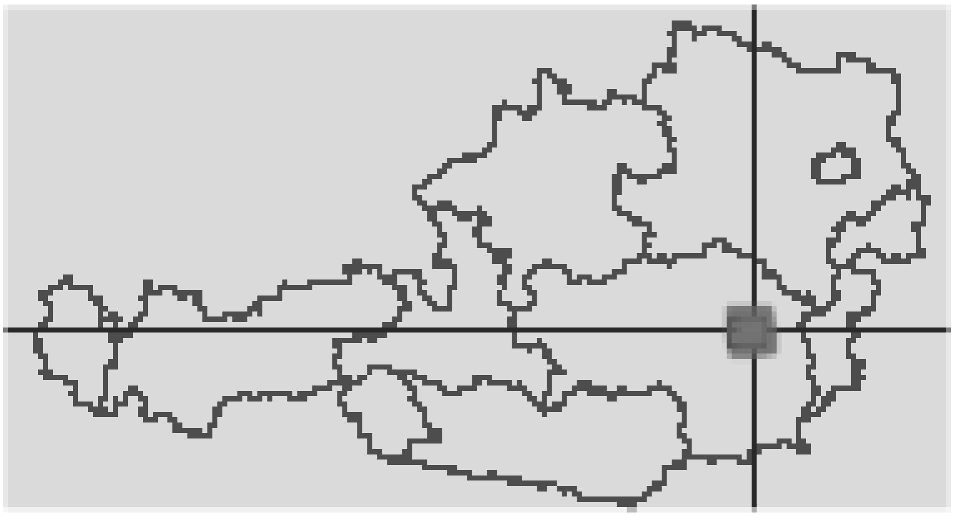

Fig. 3 – Overview: The investigated area around the communities of Gasen and Haslau (grey rectangle) in the Province of Styria, Austria

For this reason, a newly-developed system to determine spatial and temporal precipitation distribution was applied. This approach is called INCA (Integrated Nowcasting through Comprehensive Analyses) and is operated by the Central Institute for Meteorology and Geodynamics in Vienna (ZAMG). INCA is a well-developed analysis and forecasting system for various meteorological parameters, including precipitation, wind and temperature. The system uses weather radar values, which are pre-scaled and actually scaled with ground measuring stations. The minimal time step is 15 minutes and can be added to any longer time steps (Haiden *et al.*, 2006). Due to reliable radar data and moderate precipitation intensities, a high-quality spatial pattern of precipitation sums could be provided (Fig. 4). The estimation of absolute precipitation intensities was made on an acceptable level, about 20 % error (Andrecs *et al.,* 2007).

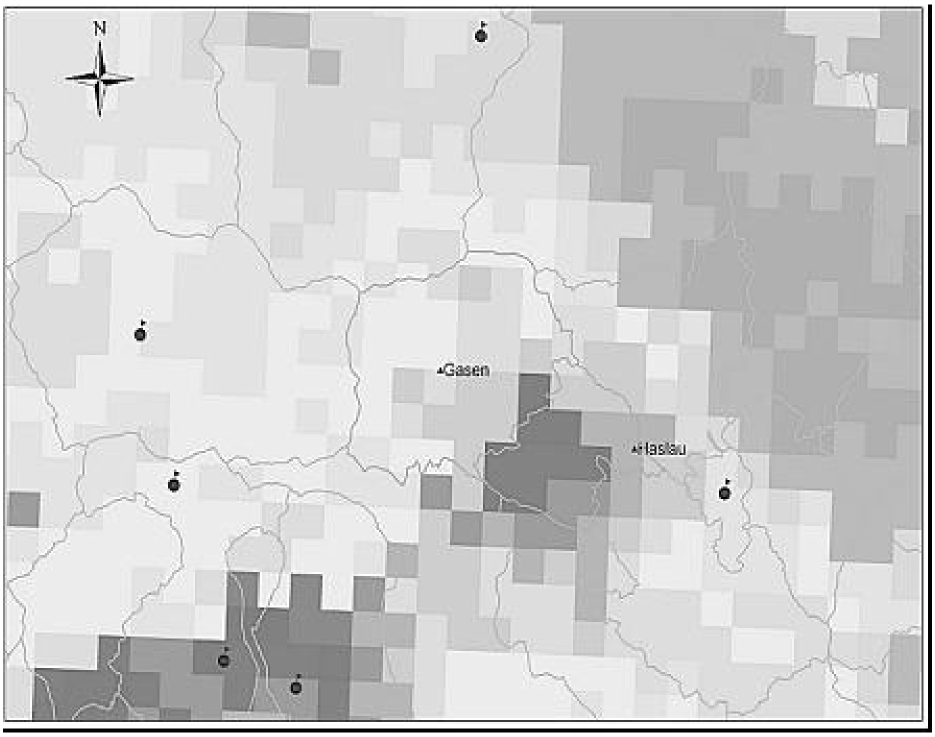

Fig. 4 – There are no gauging stations (points with a flag) in the area of the communities of Gasen and Haslau. The INCA data (raster 1*1 km) are relevant in regard of the spatial distribution of the precipitation sums (36 hrs).

3.2 Geomorphologic, geologic and pedologic information

A DEM (Digital Elevation Model, 10*10 m) is available for the whole area, probably not detailed enough to reflect relevant morphologic surface-structures. A DEM (1*1 m) based on a laser scan was prepared in some parts of the area to survey the differences of accuracies and the subsequent benefit for landslide assessment.

Due to the inadequate level of detail, the existing geological map of the area (1:200 000) could not offer significant information on landslide susceptibility.

In Austria, the BFW survey offered a digital soil map of all agricultural areas, containing various soil data, maximum accuracy of 1: 25 000. First steps were taken to determine susceptibility depending on different soil types using the so-called Ebod (electronic soil information system). The analyses showed certain soil types significantly landslide-prone. Ongoing investigation shall concretize these correlations and extend the database to the physical parameters of soil types.

3.3 Field survey

The field survey was performed by several institutions from different scientific and administrative perspectives. While the BFW survey put emphasis on the documentation of losses and (anthropogenic) triggering causes including all kinds of processes, the geological survey in Austria (GBA), for instance, focused on the relevant parameters of processes explicitly for landslides.

As a matter of fact, the field survey led to insights into documentation methods and how to best proceed in the future. The most important conclusion can be worded as follows: “Begin with the end in mind”.

Expected results in terms of spatial extent, scale and content should already be defined at the beginning of documentation. It is important to consider the available human and financial resources, methods and basic data, adapting scale and survey methods accordingly. Not surveyed input data can rarely be found later in other reports. Since there is neither quantified nor standardized collected information, conclusions are limited. It is crucial to identify the purpose of documentation. Should this documentation concentrate on:

- An overview of losses or a monetary valuation of disasters?
- The development of better insights into the process?
- The advancement and development of hazard and risk assessment tools?
- The development of an applied disaster management plan?

3.4 Remote sensing

New techniques of remote sensing provide helpful data to locate landslides (field survey), to assess process areas (Fig. 5), to identify the susceptibility of slopes and to improve basic data like for instance of the land cover or the road and path network.

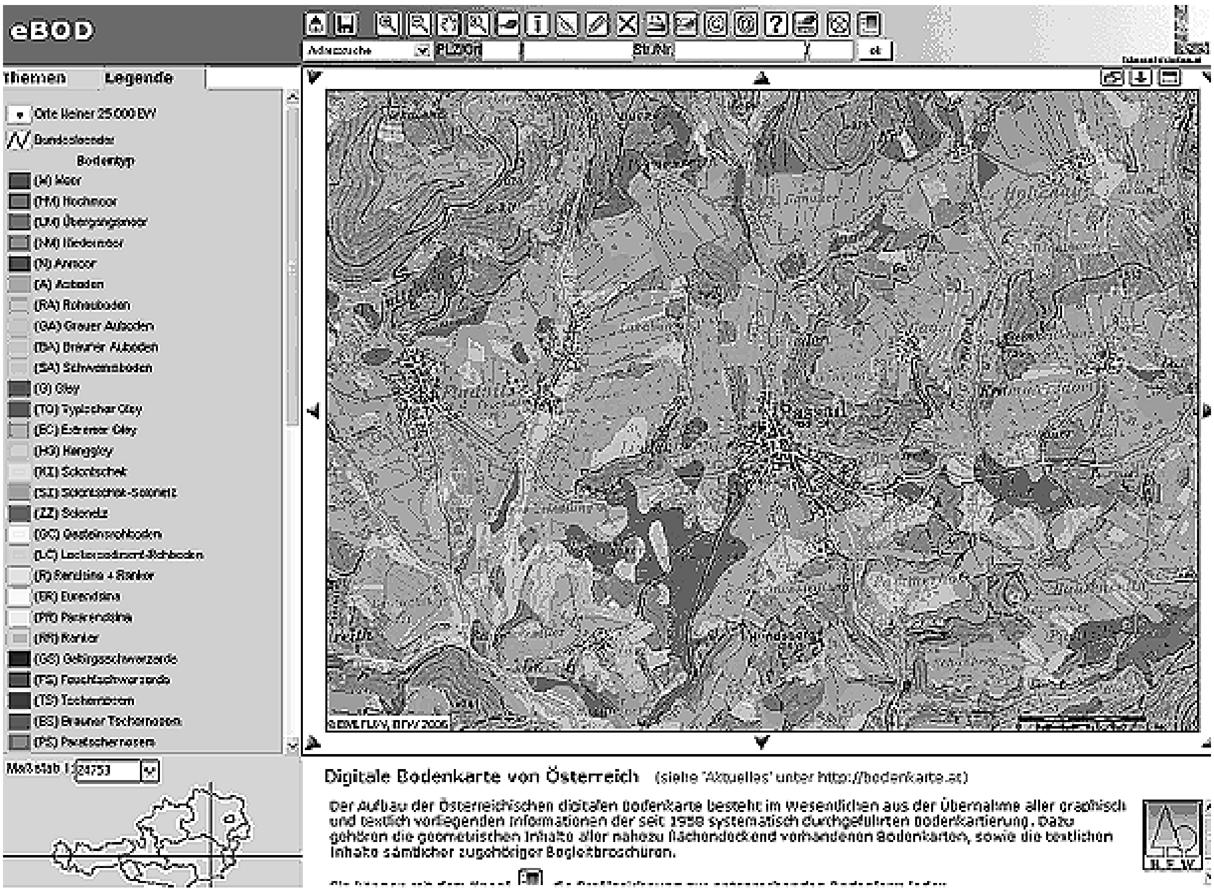

Fig. 5 – This area-wide (Austria) digital soil map contains various soil data, e.g. soil type, water supply, permeability and soil depth (Ebod).

The Gasen aerial images from parts of the affected area where taken about three weeks after the event. The assessment and limitation of the landslide starting zones were subdivided into three categories:

- secure
- assumed
- indication

While the probability for a secure assessment in open land was high, estimating small landslides in forests areas was problematic. However, there was sometimes an indication of previous events.

The delimitation between transport and deposition zones is partially subjective. Due to delayed flights after the event, several deposition zones had already been cleared, which gave rise to misinterpretations.

LANDSLIDE HAZARD ASSESSMENT – CRUCIAL POINTS

Operations to pursue proper assessment of spontaneous landslide-prone areas, as well as the identification of endangered areas need comprehensive area and parameter information. Slope susceptibility depends on many parameters such as area inclination, morphology, soil type (grain size, structure, water regime, friction angle) and thickness of loose material. Vegetation interacting with the soil type is also relevant due to its influence on the water regime. The topographical position of the fracture line, material properties (viscosity) and surface conditions (roughness…) are relevant to material transport and deposition. Furthermore, susceptibility of slopes changes with the development of mass movements. In order to predict spontaneous landslides in terms of spatial occurrence, a homogeneous and area-wide documentation of landslides and their triggering mechanisms is required. Such data allow for the assessment of slope susceptibility by using statistical analyses of parameters and parameter combinations (Fig. 6).

Fig. 6 – Classification of landslides and debris flow in starting, transport and deposition zones based on aerial images (Haslau, Joanneum Research, Tilch & Kociu 2007).

Localizing endangered areas, evaluating slope susceptibility has to be completed by an assessment of transport trajectories of landslide-entailed processes and the range of the displaced mass. Commonly, spontaneous landslides-entailed processes develop into “slope debris flow”. These rapid processes mean hazards cropping up even in flat areas that are not directly landslide-prone. High velocities may cause considerable damage even with small sliding volumes. Because of their affinities to avalanche transport mechanism developing, energy curve-based avalanche models to estimate the affected area in case of landslides and debris flow seems to be a promising approach.

In single debris flow events, mass transport velocities, pressures and deposition depths can be determined by modeling these events (e. g. with Flo2D) in order to assess the hazards in detail. At present, these models are not applicable throughout the area.

Climate change, socio-economic and risk assessment

“Landslides present a threat to life and livelihood throughout the world, ranging from minor distribution to social and economic catastrophe” (Crozier & Galde 2005). The threat by natural hazards such as landslides is not constant; it varies according to background conditions. Climate change influences directly the probability of landslide events by varying intensities of precipitation. Socio-economic issues affect hazards directly because susceptibility of slopes is influenced by changes in land use (vegetation, constructions such as forest roads Fig. 7, a. s. o.).

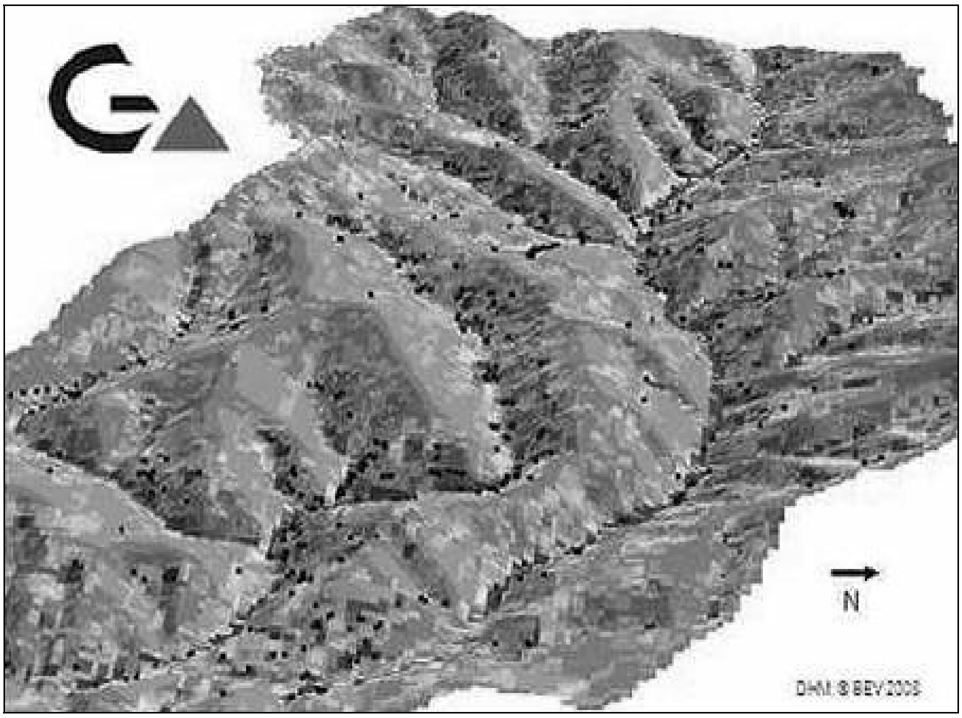

Fig. 7 – Hazard index map for landslides in the communities of Gasen and Haslau (Schwarz & Tilch 2008), based on a neuronal network approach.

According to the formula “risk = hazard * vulnerability” there have to be valuable structures in the affected areas which document the risk of losses. The risk of economic or anthropogenic losses is the real value of public interest, and of course this risk depends directly on the value of those structures in the affected areas. Satisfying socio-economic development (in the alpine region) led to considerable increase in losses over the last decades (Fig. 8), even without taking into account the climate change effects (WIFO 2008).

Existing hazard and risk assessments have to be updated according to the rate of socioeconomic and climatic changes, methods have to be transparent to argue comprehensible changes of endangered areas.

Fig. 7 – Landslide triggered off by improper forest road dewatering (Haslau 2005).

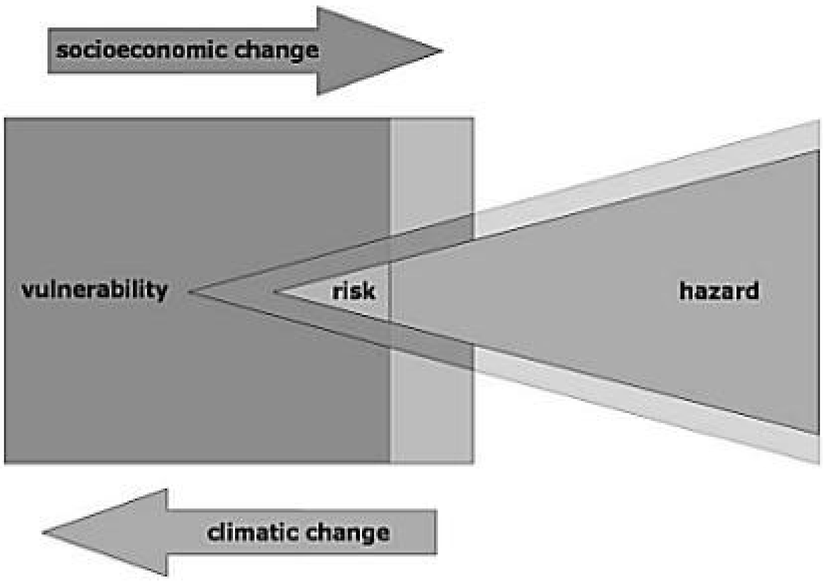

Fig. 8 – Schematic relation between risk, hazard and vulnerability. Changes of hazards and vulnerability (caused by socio-economic development) may reduce or increase the risk.

WHAT NEEDS TO BE DONE

From the perspective of the above analysis it is evident that each scientific or methodological progress, as well as enhanced spatial hazard and risk assessment of spontaneous landslides need a proper and homogeneous landslide inventory. This activity should be institutionalized!

The everlasting conflict between decreasing quality and data availability when increasing the geographical range can be solved by applying a "top-down strategy" on different scales (levels of accuracy), ranging from Pan-European summary maps and regional land use planning to detailed planning of preventive measures.

Although everybody talks about risk assessment, it is well known that often the second part of the equation (risk = hazard * vulnerability) is largely neglected in practice. As a matter of fact, essential methods to estimate the frequency and magnitude of spontaneous landslides are rare. Therefore, this should be a priority task.

In order to evaluate the consequences of climate change and what it means to the risks of landslides, it is necessary to have high-quality databases of current "risk level", but they are not available yet for most of the Alpine area and for other mountainous regions.

REFERENCES

Andrecs, P., Hagen, K., Lang, E., Stary, U., Gartner, K., Herzberger, E., Riedel, F., Haiden, T. (2007), *Documentation and Analyses of Disasters 2005 in the Communities of Gasen and Haslau (Styria)*, BFW-Documentation 6, Wien.

BMLFUW (2006), *Hochwasser 2005, Erignisdokumentation, Teilbericht der Wildbach und Lawinenverbauung*, BMLFUW, Wien.

Crozier, M.J., Galde, T. (2005), *Landslide hazard and risk: issues, concepts and approach*, in Glade T., Anderson M.B., Crozier, M.J (Hrsg.), *Landslide hazard and risk*, Wiley, Chiechester.

Cruden, D.M., Varnes, D.J. (1996), *Landslide types and processes*, in *A.K Turner and R.L. Schuster (Hrsg), landslides: investigation and mitigation*, Special Report, Nacional Academey Press, Washington D.C.

Ebod, (http://gis.lebensministerium.at/ebod/frames/index.php?&gui_id=eBOD).

Haiden, T., Kann, A., Stadlbacher, K., Steinheiner, M., Wittmann, G. (2006), *Integrated Nowcasting through Comprehensive Analysis (INCA), System overview*, ZAMG Report, Vienna.

Hydrographischer Landesdienst der Steiermark (2005), *Niederschlagswerte der Stationen in der Steiermark* (values), Graz.

Koicu, A., Tilch, N. (2005), *Der Katastrophenmonat August 2005 – Bestandesaufnahme und erste Bewertung der Massenbewegungen im Bezirk Weiz (Oststeiermark)*, 7, Geoforum Umhaussen, Geologische Bundesanstalt, Wien.

Schwab, J.C., Gori, P.L., Jeer, S. (2005), *Landslide Hazards and Planing*, American Planning Association, Report Nr. 533/534, Chicago.

Schwarz, L., Tilch, N. (2008), *Möglichkeiten und Limitierungen der Regionalisierung mittels Neuronaler Netze am Beispiel einer Rutschungsanfälligkeitskarte für die Region Gasen-Haslau*, in Strobl, J., Blaschke, T., Griesebner, G. (2008), Angewandte Geoinformatik 2008, Beiträge zum 20, AGIT-Symposium, Salzburg.

Tilch, N., Kociu, A. (2007), *Bericht zum Projekt: Abschätzung der Risikodisposition für Rutschungen und Hangbewegungen am Beispiel Gasen/Haslau (Stmk)*, Geologische Bundesanstalt, Wien.

WIFO – Austrian Institute of Economic Research (2008), *Eine volkswirtschaftliche Analyse der Wildbach- und Lawinenverbauung,* WIFO, Wien.

Received June 15, 2009