DEVELOPMENT OF A WEB-MAPPING EXPERT TOOL FOR HAZARD ASSESSMENT IN ALPINE VALLEYS

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ABSTRACT

Switzerland is exposed to a wide variety of natural hazards especially in its alpine valleys, often leading to substantial loss of life, damage to property or infrastructure. In order to offer a solid infrastructure, a web-mapping expert-tool is being developed by the Natural Hazards Research Network at ETH Zurich.

This tool provides a platform for trans-disciplinary projects. A declared mandate is to develop cross-boundary avenues to explore the relation between different hazard processes as well as their combined effects on the natural and social environment. The final product will be a geo-portal for spatial hazard assessment and risk mapping.

In order to be accessible to a large range of experts and decision makers such as public authorities or politicians, an experimental two-level user interface is being developed: one for trained specialists, and a second one based on the concept of Atlas Information Systems.

1 INTRODUCTION

Switzerland has always been exposed to a wide variety of natural hazards happening most frequently in its alpine valleys [Fig. 1]. In addition, according to the Swiss Advisory Body on Climate Change [8], climatic changes bring a growth rate of natural event damages of about 5.2 % per year. Thus, the need for an integrated natural hazard management and sustainable hazard prevention culture became obvious. At the Swiss Federal Institute of Technology, methods are developed and improved in order to identify areas affected by natural hazards, and to define parameters allowing quantification of static and dynamic impacts on structures in these areas.

HazNETH, the Research Network on Natural Hazards at ETH Zurich, combines the expertise of twelve specialized institutes in natural hazards processes. It provides a platform for trans-disciplinary projects focusing on natural hazard research in order to improve methods and tools for integrated risk management as a base for sustainable development. HazNETH supports an online geospatial hazard information system that allows the project partners to share and analyze their thematic geodata. Apart from standard webGIS functionalities, the application provides expert tools specifically tailored to interdisciplinary hazard research needs. A very flexible ergonomic and intuitive graphical user interface, which lives up to the needs of the various user groups, has been developed. This intuitive concept of Atlas Information System guides such non-specialists users as emergency organizations, public authorities, or politicians through the application.

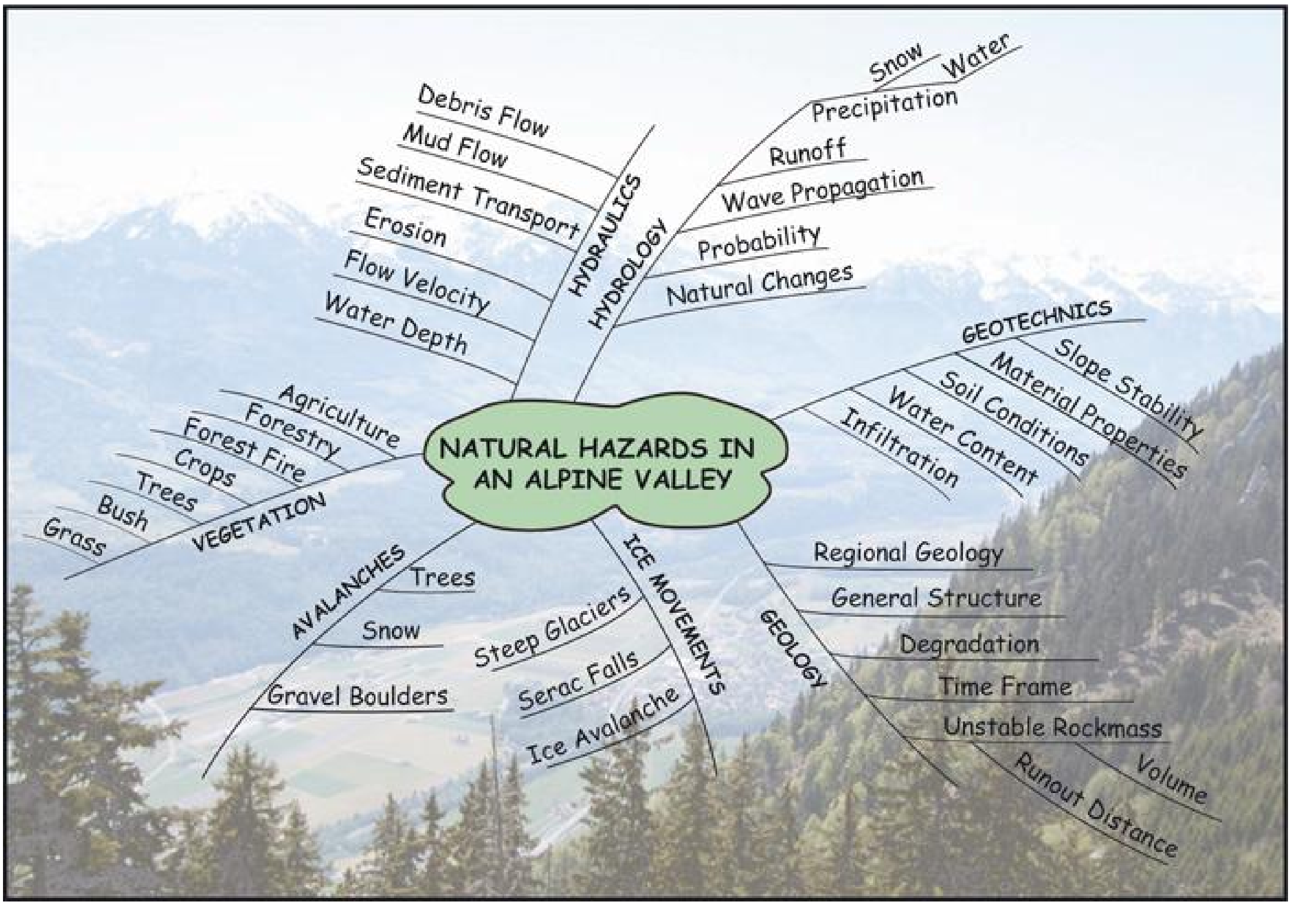

Fig. 1 Different phenomena acting as natural hazards in an alpine valley

2 MATERIAL AND METHODS

2.1 Data and database

Database components

The HazNETH geodatabase is made up of three data groups: Initial data, Process data, and Hazard data.

- The Initial data consists of raw data or data showing a degree of processing that is usually used by researchers. This part groups a large range of data types from raw data, as for example water flow-rate in a river cross-section, to data keeping different degrees of processing: geological maps, satellite images, or earthquakes hypocenters. An excerpt of the main categories of initial data is shown in Table 1.
- The Process data part contains the outputs of process base, statistical, or empirical modeling procedures applied to analyze natural hazard phenomena.
- The Hazard data is divided in two sections. One is the cadastre (spatial and time inventory) of the various natural hazards and the second is composed by derived hazards maps.

Data Category	General data groups	Data-sets
Topography	- Data groups Vector 25	
Remote imagery	- Aerial photography - Satellite imaging	- aerial photos
DEM		- DEM 10 – 25 - 50 - DEM high resolution for the specific site (1-10)
Geology	- Geological maps	- geological maps(1:25,000) - rock maps (lithology, bedding orientation, fracturing etc.) - borehole data - sediments thickness (field measurements) - quaternary geology - bedrock depth - infiltration, water content, succession pressure
Geotechnics		- in situ and labor data of soil properties - rock strength + deformability + density - fracture friction angle
Geomorphology		- geomorphologic maps + features - faulting/joining (local information) - type and previous land-sliding - type and previous channel processes - past history of liquefaction - displacements 2D + time - displacements 3D + time
Tectonic		- tectonic map - faults + dip & strike (3D info)
Surface hydrology	- Water - snow	- hydrological data
	- Glaciers	- Depth
		- deposits below water-table - groundwater table + variation in time - infiltration rate, water pressure, hydraulic head
Hydrogeology	- Precipitation (heavy periods)	- rainstorm intensity and duration (time series) - return levels of point /area precipitation - time series of observed precipitation - snow/rain partitioning
Meteorology	- Wind	- cyclone tracks - cyclone depth / geostrophic wind return levels
	- Temperature	- temperature time-series
	- Radar images	- space images - ground based images
	- Radio/spectrometer / Balloon soundings	
Etc.		

Tab. 1 Excerpt of main initial data categories

Data models identification

In order to set up the database, several data-models were analyzed. The chosen solution was to design a data model taking into account the specificity of natural hazards of Switzerland and focusing on alpine valleys. However, taking into account the complexity of phenomena that occur in an alpine valley, the design process of the database represents a continuous task. The design process is based on the experience achieved during the GEOWARN project by the Institute of Cartography of ETH Zurich in developing a geo-spatial database concept for data-management of dormant volcanoes [6]. Two other data-models constitute sources of inspiration for the design process: ArcHydro data model - developed by ESRI for managing surface water resources and HYGES - developed by University of Liege for managing groundwater resources [7,4].

Data collection

Depending on the spatial extent and local distribution of natural hazard phenomena, three spatial scales of data collection and analysis were identified:

- **General Level**: Switzerland (country). The Country level covers entire Switzerland and to some extent neighboring countries, taking into account that natural phenomena could not be stopped by administration boundaries. Phenomena like earthquakes or other various tectonic phenomena could be represented here.
- **Regional Level**: Wallis (river basin). The Regional Level datasets were collected for an entire hydrological system, a river basin, which roughly corresponds to the administrative boundaries of Swiss Canton Wallis. The research focus on the regional level is directed towards natural hazards that concern the whole river basin.
- **Local Level**: (alpine valley). The Local level (alpine valley) is targeting natural hazard phenomena occurring at a local level including landslides, torrent streams, debris flows, glaciers hazard events, etc. The datasets for this level were generally sampled at a higher resolution than for the other two levels. The local level is the current working pilot scale.

2.2 Techniques and technologies used

With regard to the objectives and requirements described in the introduction, as well as the large among of thematic data described previously, we decided to implement the system as a multi-tier architecture: Internet client, application server with web server and spatial engine, and spatially enabled database [Fig. 2].

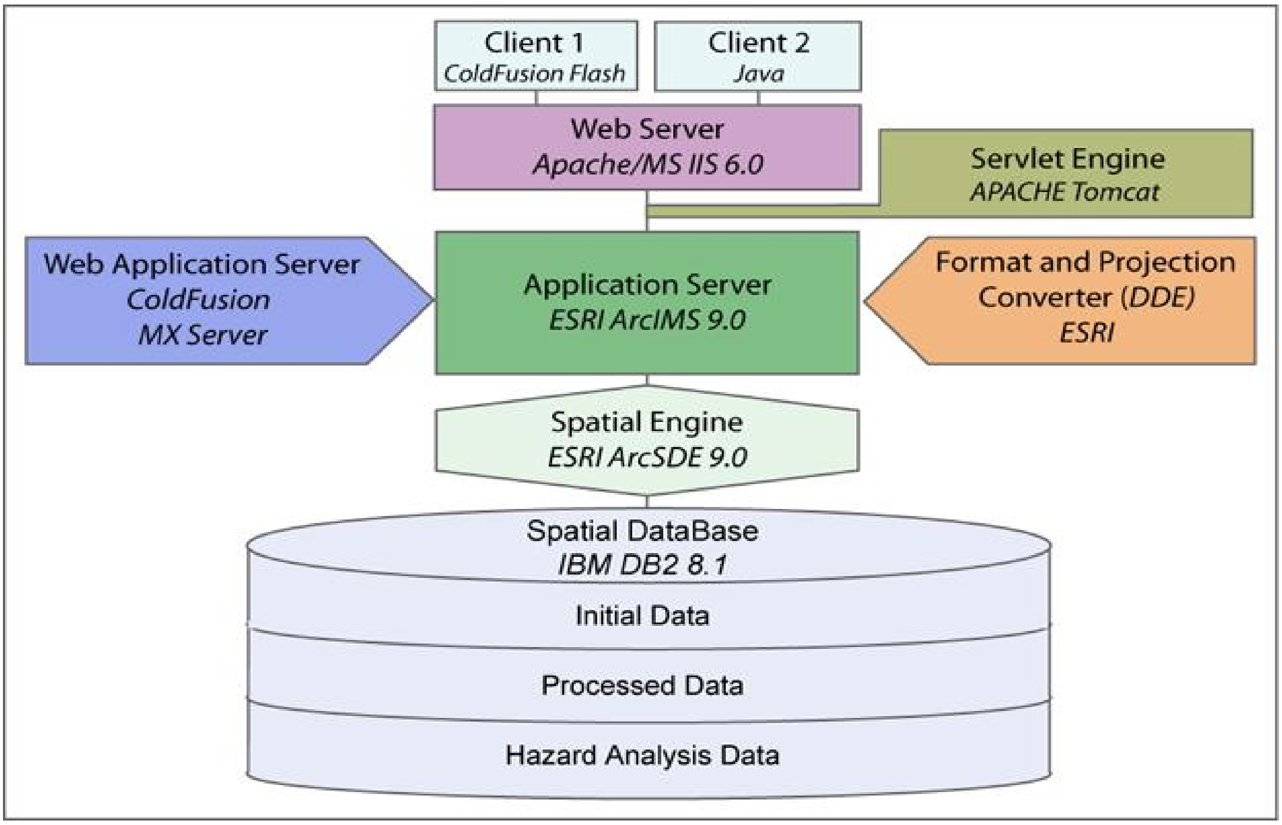

Fig. 2 System implementation

Dynamic map content, geodata, and hazard analysis services are delivered via the web using ArcIMS. This software, developed by ESRI, provides a highly scalable framework for geodata visualization, analysis, and publishing, which meets HazNETH's needs. The choice of this product over an open source product or another commercial system was made along the following criteria; most of the HazNETH partners currently work with ESRI products, and therefore store their geodata in the corresponding formats. The possibility of developing natural hazard custom applications, as well as the good reputation of the product, and its ease of use and administration made the ESRI software more attractive.

Complementary to ArcIMS, an engine is needed to access and index spatial geodata -ArcSDE. This ESRI server software product is used to access massively large, multi-user geographic databases. Its primary roles are to provide a suite of services that enhance data management performance, but also to offer configuration flexibility, and to provide additional spatial functionalities.

In order to enable users to easily select, export, and deliver data in multiple formats and projections, HazTool uses the ArcIMS Data Delivery extension. This tool allows users to upload/download geodata in 20 different spatial formats corresponding to industry standards and to project features to a variety of projections.

As database management software IBM DB2® Universal Database™ with Spatial Extender was selected. This powerful multi-user geographic database was chosen according to its high performance, its capacity to store extremely large data volumes, and its compatibility with ArcSDE.

2.3 Standards used

To overcome the growing amount of heterogeneous data as well as the lack of interoperability between systems, we follow the current tendency of Community Environmental Policy overseen by INSPIRE (Infrastructure for Spatial Information in Europe).
This European initiative establishes an infrastructure for spatial information that will help to make spatial or geographical information more accessible and interoperable for a wide range of purposes supporting sustainable development. It tries to regulate spatial data and data server harmonization through the establishment of integrated spatial information services, based upon a distributed network of databases, linked by common standards and protocols to ensure compatibility.
Thus, in order to allow a future world web network for hazard data, the following specifications and standards are used:

OGC standards:
• Web Map Service standard (WMS)
• Web Feature Service standard (WFS)
• Web Coverage Service standard (WCS)

ISO standards:
• ISO 19115: Metadata standard
• ISO 19139: Metadata Implementation Specification standard
• ISO 19136: Geographic Markup Language (GML) standard

3 RESULTS

The system developed by HazNETH currently supports two distinct projects. These projects, described below, brought the first feedbacks and above all the usefulness validation. The continuity of these projects allows a constant tuning and improvement of the application.

3.1 Risk Screening

Mountainous regions are typically subjected to various natural hazards simultaneously; as a consequence, experts from various fields are involved in the assessment of these processes. Even within the governmental bodies, the responsibility for the planning of mitigation actions is often divided among different departments. The detailing of the risk assessment thus greatly varies between different process types. Furthermore, the experts who model the hazardous processes are often not fully aware of the potential consequences due to limited knowledge of the local conditions. These facts hinder an overview on the total risk from natural hazards to which a region is exposed and thus represent a drawback to an integral management of natural hazard risks. The aim of the risk screening is to overcome these drawbacks in an efficient manner. The core of the risk screening is a big workshop where experts in natural hazards, representatives from the authorities and experienced locals are jointly consulted.

Prior to the risk-screening workshop, the relevant information regarding the hazardous processes and the potential consequences must be collected and processed to ensure an efficient procedure during the workshop. The web-mapping expert-tool for hazard assessment can provide the framework for this task. For this purpose, all available information is collected and inputted in the system. It is not required that all information is of the same level of detail, instead the focus should be set on the completeness of the information. Whereas the available information for some processes is of spatial nature (such as danger maps used for land-use planning), other processes are represented simply by points indicating that an event has been observed or that a study has been performed for this location. Information on the potential consequences is typically data on land-use, traffic networks and other infrastructure facilities.

During the risk-screening workshop, all participants are asked a series of formalized questions, related to the probability of occurrence and the potential consequences of the considered process, taking into account the different potential magnitudes of the event. Such an interviewing process is documented in detail in EBP [2]. The application must support the workshop by representing all available information in a way that is easily comprehensible for laypersons. Especially the treatment of the effect of joint occurrence of processes, which is common in natural hazards, requires that the available information on different process types is jointly presented [9].

The results of the risk-screening workshop are represented by the web-mapping tool to facilitate an overview on the spatial distribution of the risks, as well as by a synthesis map [Fig. 3].

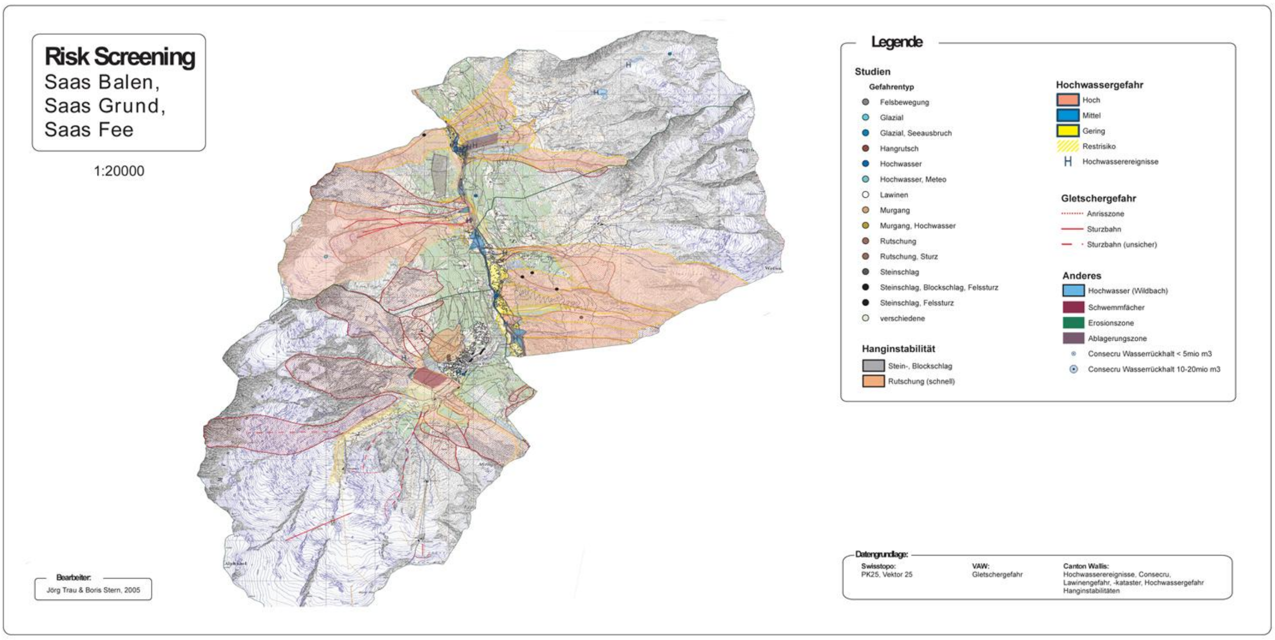

Fig. 3 Rough risk screening result map

3.2 Integrated Hazard Analysis

In addition to the classic parallel multi-hazard assessment process, a process-based combined multi-hazard assessment procedure, or "Integrated Hazard Analysis", is being developed within the application framework. Figure 4 shows an overview of the main steps of a parallel multi-hazard assessment process.

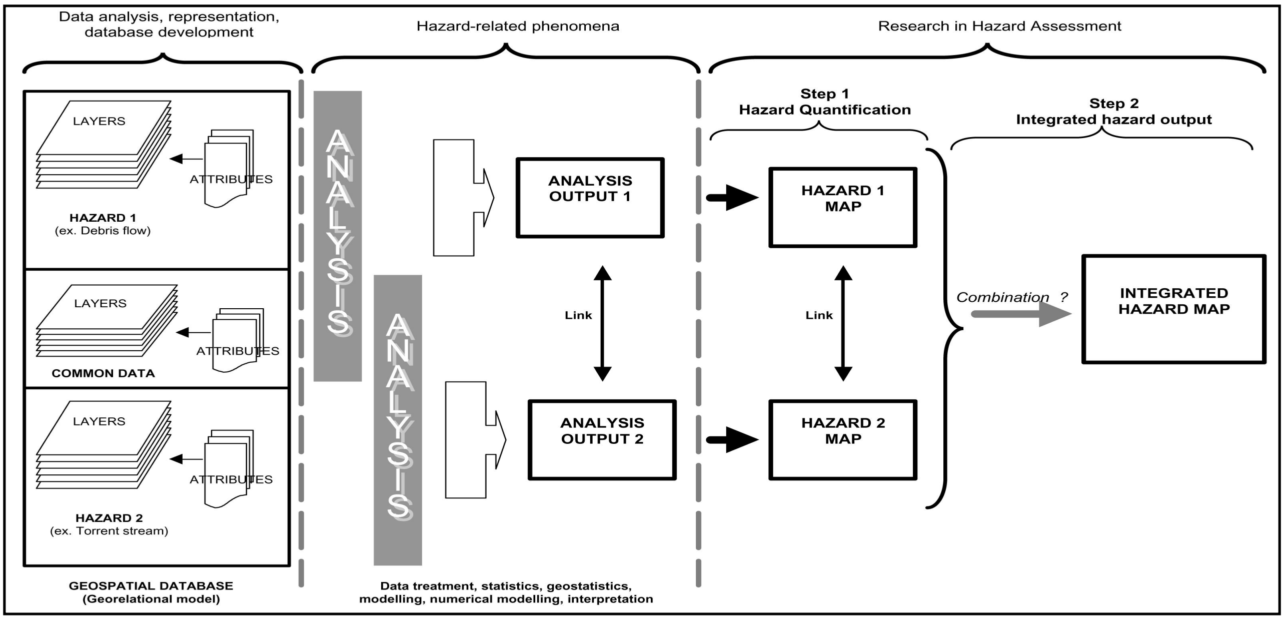

Fig. 4 Overview of the main steps in a parallel multi-hazard assessment process

The main goal of the "Integrated Hazard Analysis" is to find methods that combine related hazards in order to obtain an integrated hazard representation. The hazard quantification procedure will be developed as routines and tools, following currently used modeling procedures, [13,1,10,12,11,3,5,14] in natural hazard process-based research. A pilot study using debris flow and torrential flood hazards is being realized. A first approach to explore this uses the web-mapping expert-tool to spatially query the database. The query results then serve as input data to a hazard quantification routine based on the first project step. By using a box model approach as a first step and subsequently more sophisticated multidimensional approach (e.g., finite-element model), a combined hazard zonation is computed for the defined cross-section or area, for a combination of two hazards (i.e., the likely simultaneous occurrence of torrent stream and debris flow events). The individual algorithms used for this modeling routine are taken from established (published) process-based numerical models applicable to debris flows and torrent streams. Data queried could include, for instance vegetation parameters, topography and slope characteristics, runoff, geological substrate, soil data (e.g., texture, mineralogy, cohesion, substrate adhesion), meteorological data (e.g., rainfall and humidity), inhomogeneities (such as anthropogenic structures, tectonic structures, unconformities etc), etc.

In Figure 5a, a mountain valley is shown to serve as an example. Figure 5c shows the schematic result of a parallel multi-hazard assessment routine, displaying hazard zones for two distinct hazard groups (torrent streams and debris flows), and the areas of their overlap. In this conventional parallel "overlay" approach, the areas downhill of the combined hazard zones are underestimated in terms of their hazard potential (e.g., profile P-P' in Fig. 5b & c): a debris flow (hazard zone A) will supply fresh loose material for mobilization and transport within the hazard zone (B) of a torrent stream event, if B occurs subsequently or simultaneously to A. This demonstrates the need to combine hazards (e.g., A + B) in an integral manner.

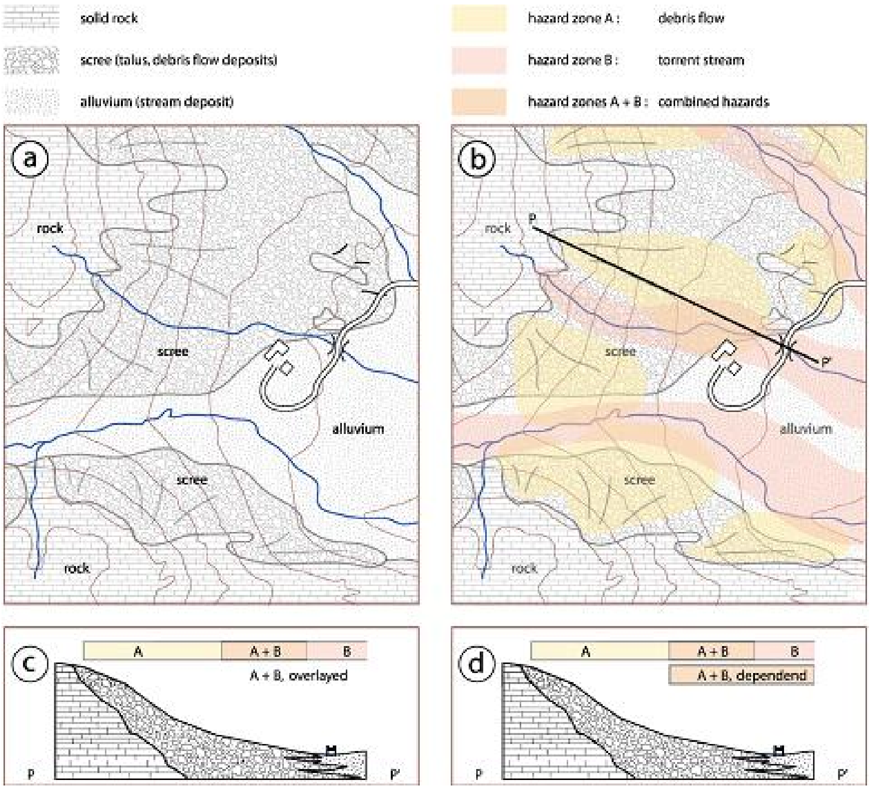

Fig. 5 A conceptual example of an integrated multi-hazard assessment procedure

Process-based modeling approaches (numerical, statistical, geostatistical and others) will be used as inputs for the hazard assessment analysis. A better result than simple overlays can be obtained (Fig. 5d), where the interdependence of both processes is taken into account ("A + B, dependent"), leading to a more realistic hazard zonation.

4 DISCUSSION

An initial step was to organize several interviews and surveys with the users. The following list describes the identified user groups and their characteristics:

- The HazNETH partners: experienced scientists with good GIS knowledge; their main interest is to combine their own information with the partners' information; they need access to all datasets with unlimited download/upload possibilities.
- The "Section dangers naturels" (Natural Hazard Office of Canton Wallis) and "Section des routes et des cours d'eau" (Division of Roads and Rivers of Canton Wallis): field specialists who work with the local council and natural hazards engineering companies for risk assessment; their main interest is to consult the HazTool system in order to manage building planning permissions; they need access to all datasets with visualization/download permissions.
- Guest users: interested persons with limited visualization permissions.

Based on the aforementioned list, general objectives and priorities for the system were defined. The needs of the different user groups with none to expert experience in using computer systems have to be satisfied. Therefore, an easy to manipulate two-levels user interface is being designed to facilitate access to information and visualization, and the use of analysis tools. Two other system priorities are on-the-fly creation of high quality web maps and integration of real-time data.
However, through the risk-screening analysis and some first feedbacks, some general open questions were swiftly pointed out, as shown in the following statements.

4.1 Transfer the correct information to the map

A conceptual cartographic problem still remains; the crucial problem of transferring the correct information to the user. A typical example would be the classical problem of scale -zooming causes a change in scale and related with that change is a shift in the cartographic generalization. Only by changing the cartographic generalization can visualization be adjusted to a user-selected scale. But, for example, the avalanche hazard maps are created by experts at and for 1 : 25 000 scale use, but often displayed at bigger scales. So a question arises, should we allow users to zoom in and out of the avalanche hazard map, according to the imprecision due to generalization at 1 : 25 000 scale for visualization aims? The classical solution is to allow it, but to display metadata specifying the conditions and limitations of use of this information. But how many users will really accurately read this information? Few we guess.
The following realistic solutions could also be used in order to achieve such a shift:

- Vary outline thickness, or surface hatching density, according to zoom factor.
- Fading in and out of specific layers that can only be displayed within defined map scale ranges.

In every case user tests have to be realized and the corresponding online satisfaction questionnaires analyzed in order to validate and fine-tune the chosen solution.

4.2 Risk mapping and Internet

The publication of hazard data and maps on the Internet implies the emergence of potential unspecialized users in the debate. Therefore, the interpretation of the correct message and the information's clarity should be considered as essential. But hazards data and maps are mostly conceived by and for technicians or engineers. So, they can easily mislead and bring interpretations errors to the common users. Thus, it was decided that the information must be adapted to its target: here again the two-levels user interfaces will be used: one for trained specialists, and the second for less experienced users.

CONCLUSION

The construction of a web-mapping expert tool for natural hazard assessment is a versatile and far-reaching challenge that covers database conception and population, data processing, as well as the development of high quality cartographic functionalities. Finally, the described project provides a knowledge base and network with easy-to-use web based client software for experienced and non-experienced users when considering natural hazard prevention and protection.

And yet we only catch a glimpse of the huge potential of such a web-tool. But we can already affirm that data are certainly going to lack, because maintaining an exhaustive, accurate, and up-to-date database, even for a small part of Switzerland, still remains a big challenge.

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BIOGRAPHY

Boris Stern studied geomatic at the National School of Geographic Sciences (Paris, France). Since 2001 he is assistant at the Institute of Cartography at the Swiss Federal Institute of Technology (ETH) in Zurich (Switzerland). He started a Ph.D. thesis in 2004 titled “Multimedia Information System for Natural Hazard Analysis”. His major areas of interest lie in geomatic, cartography, programming and Internet technologies. He is presently working on several projects dealing with web-mapping platforms.