MULTI-HAZARD EXPOSURE ANALYSES WITH MULTIRISK

- A PLATFORM FOR USER-FRIENDLY ANALYSES

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ABSTRACT

Examples from all over the world show us dramatically, that specific regions are not only exposed – and affected – by one single natural hazards, but very often exposed to multiple hazards. For example, villages located in mountain valleys might be exposed to floods and landslides in summer, snow avalanches in winter and earthquakes throughout the year. Commonly, the different natural hazards are addressed by highly advanced analysis focussing on one process type only. The respective models are perfectly adapted to the specific purpose, however, the results are very difficult to compare due to the often totally different nature of the process models. This is in contrast to the general demand on information on natural hazards, which requires comparable information on the different hazards and additionally knowledge on the relation between and influence of the different processes on each other. In order to address these requirements, the MultiRISK platform consisting of a modelling tool and an end-user driven web-based visualization scheme has been developed. Both concepts are briefly introduced in this contribution. Furthermore, an example is given for the study region of Barcelonnette (south French Alps). The final results calculated with the MultiRISK platform for the Barcelonnette region have indeed still several shortcomings. It is shown however, that such a platform offers numerous assets and advantages which might be a valuable support of agencies responsible for dealing with the effect of multiple natural hazards and consequent risks.

Keywords: Multi-hazard risk, hazard interactions, web-based service

BACKGROUND

Numerous disasters from all over the world have dramatically shown us the importance of multi-hazard risk studies. For example, an earthquake with Ms 8.0 occurred in 2008 in the Wenchuan province in China (Ciu et al., 2010). Numerous houses were destroyed and overall fatalities are very high. Besides the collapsing building, the earthquake caused also numerous landslides including rock falls and debris flows, but also liquefaction and subsidence (Huang and Jiang, 2010). Some of the large scale landslides blocked even rivers and lakes were formed behind the natural dams. The breakthrough of the lakes caused than dramatic floods (Cao et al., 2011). This is only one example to demonstrate that a given region area might be affected by more than one natural hazard and that some of the natural hazards are closely linked, some directly and others with a lag time. Therefore, multi-hazard risk assessments are required to address that problem adequately.

Multi-hazard risk analyses (MHRA) are the first step of comprehensive risk management for an overall risk reduction. Herein, all relevant hazards in an area of interest are considered. However, their performance raises a number of challenges in comparison to single-hazard risk analyses. This includes the direct comparability of hazards (e.g. inundation depth versus wind speed), differences in hazard modelling and vulnerability assessment methods, and interactions between processes, to name some only. To overcome the associated challenges, a coherent analysis scheme is advisable.

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MHRA consist of a multitude of single steps and their performance is therefore time-consuming and error-prone. The software tools HAZUS in the USA (FEMA, 2007), RiskScape in New Zealand (Schmidt et al., 2011) and CAPRA in Central America tackle this problem already by guiding the user through the whole procedure of a MHRA.
With the MultiRISK platform the authors developed a similar tool with the focus on the modelling of mountain hazards and exposure of elements at risk including a validation step and the final visualisation of the scenario results.

OBJECTIVE

The development of such a multi-hazard risk modelling scheme is differentiated in the modelling tool and the visualization tool. Both parts, if clearly fully linked, have however to be treated separately but continuously synchronized. The development of the overall MultiRISK – platform, including both parts, is based on the following general objectives:

- Modelling of single hazards based on similar input data.
- Validation of the modelling results.
- Analysis of the exposure of elements at risk.
- Developing a web-based visualization.

DATA AND METHODS

The MultiRISK platform has been conceptually developed based on the general assumption, that similar information available for all different natural hazards should be used in order to perform single hazard analysis, but allowing also to determine the linkages between these hazards.
First, an analysis scheme for regional multi-hazard exposure computation, based on data derived from a digital elevation model (DEM) and optionally from land use/cover and lithological information was developed. Within the multi-hazard modelling scheme, the five types of natural hazards (debris flows, rock falls, shallow landslides, snow avalanches and floods) are considered. For this purpose, simple empirical models were chosen. The same DEM was taken as input data and complemented with process related information (e.g. Table 1 for details). Examples are the definition of a threshold slope angle for the identification of potential rock fall sources under exclusion of certain lithological units, such as clays and marls, or the *Fahrböschung* (angle of reach) for the run out modelling. A detailed description of all models is beyond the scope of this contribution, for comprehensive details please refer to Kappes et al. (2012).
The following geospatial input layers are required for the different hazard models (Tab. 1 and Fig. 2).

Tab. 1 Natural hazards considered in the MultiRISK - platform with respective input data requirements.

Hazard	Geospatial input Parameters	Model	Source
Debris flows	DEM (slope angle, upslope area, planar curvature), geology and land use	Flow-R	Horton et al. (2008)
Rock falls	DEM (slope angle) and geology	Source area	Wichmann and Becht (2006), Guzzetti et al. (2003), Ayala-Carcedo et al. (2003), Jaboyedoff and Labiouse (2003), Frattini et al. (2008)
		Run-Out: Flow-R	Horton et al. (2008)
Shallow landslides	DEM (Outflow boundary length, upslope area and slope angle) and geology	SHALSTAB	Montgomery and Greenberg (2009)
Snow avalanches	DEM (planar curvature, slope angle) and land use	Release area	Barbolini et al. (2009)
		Run-Out: Flow-R	Horton et al. (2008)
Floods	DEM	Flood Area	Geomer (2008)

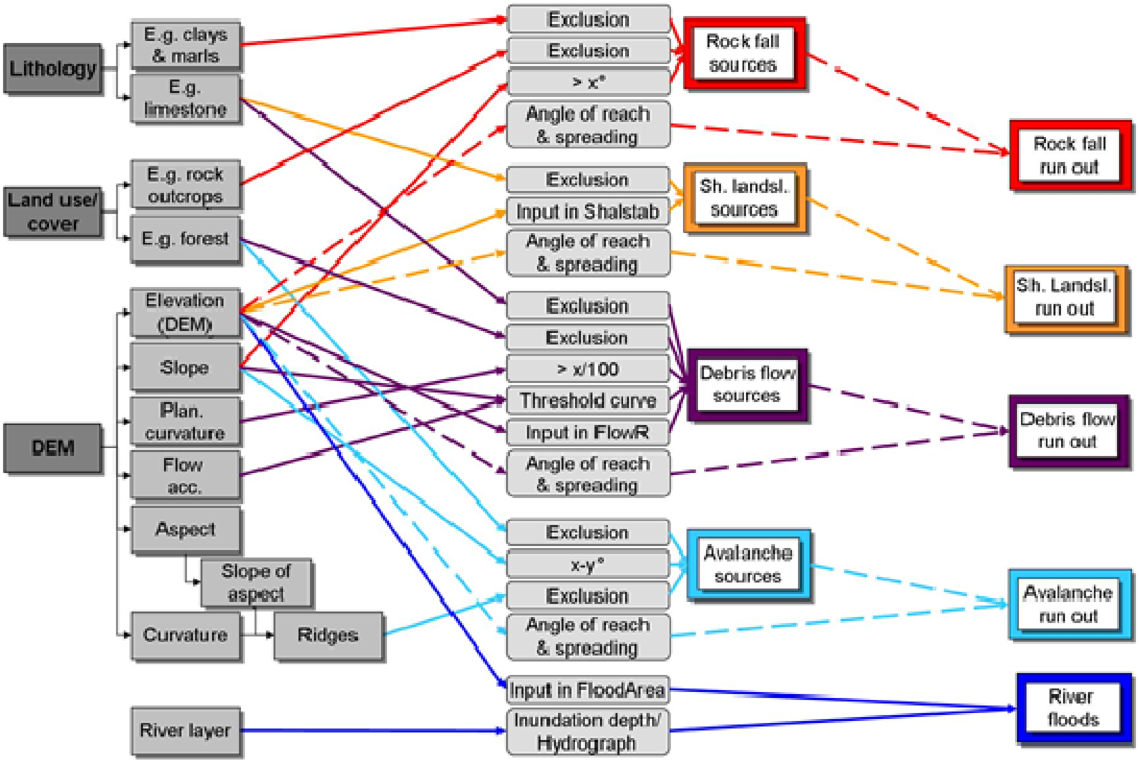

Fig. 2 Flow chart of the analysis scheme for rock fall, shallow landslides, debris flows, avalanches and floods. The principal basis for all calculations is the DEM. Respective derivatives such as slope, planar curvature or flow accumulation (medium grey boxes) are computed. Other parameters such as land use and lithology (in dark grey boxes on the left side) are optional. All data are the input for the models (light grey boxes with rounded edges). Solid lines refer to the identification of the source areas and dashed lines indicate the run out (for a detailed description, please refer to Kappes et al., 2012).

A validation step based on a confusion matrix (overlay of recorded events and modelling results, as summarized by Begueria, 2006) was included to enable the assessment of the models' quality and performance. Analysis of exposure is carried out by overlaying the resulted susceptibility zones with elements at risk.

Second, this overall analysis scheme was implemented in a new software package called "MultiRISK - Modelling Tool". It offers a fast, coherent and reproducible calculation of multi-hazard exposure. The software is programmed in Python and based on ArcGIS 9.3 tools. The user is guided step by step through the analysis procedure (Fig. 3). It starts with the definition of the project name, workspace description and upload of the input data (DEM, optional: land use/cover & lithology). In the next step "Hazard choice", the processes to be analysed are selected. In the "Parameter choice", the model parameters are entered, the choice is confirmed and the model is started. Subsequently, a validation of the modelling results with recorded events is offered. Finally, after the upload of elements at risk, those threatened by each process are identified and quantified.

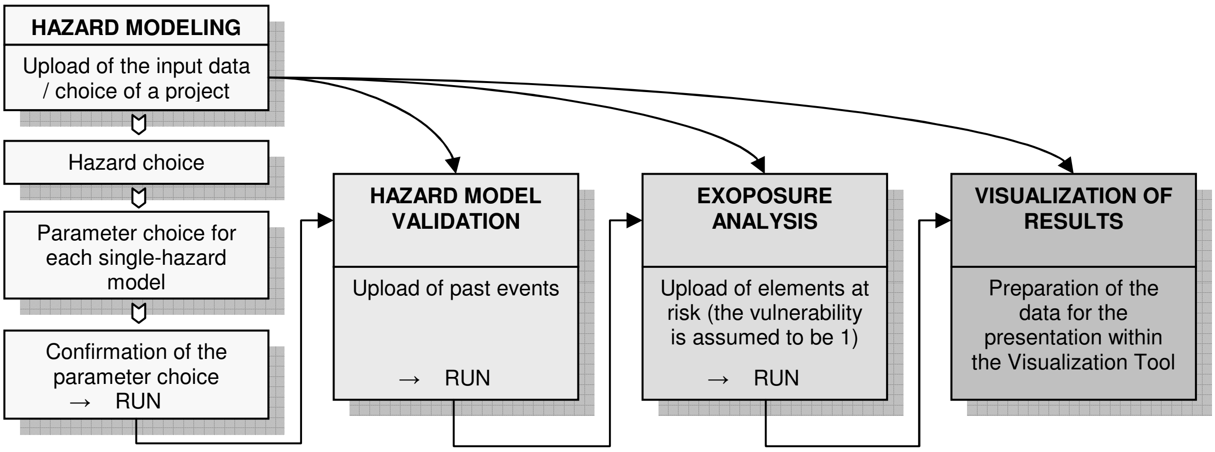

Fig. 3 Framework of the MultiRISK Modelling Tool (modified after Kappes et al., 2012).

The MultiRISK - Modelling Tool is linked to the MultiRISK - Visualization Tool since the output of the analysis is multi-dimensional and not easily accessible, especially by non-GIS/-cartography experts. The Visualization Tool takes the information for display from a defined folder in which all modelling result files are saved with pre-established names. It is a web-mapping application based on open-source CartoWeb3 in combination with MapServer as geospatial engine for the interactive mapping application. The user gets access to the information with a standard internet browser.
The information produced in the Modelling Tool is visualized stepwise, organized in seven maps/switches (Fig. 4). A series of simple web-based GIS tools allows a straightforward access of the spatial information. The maps offer the consideration of different aspects of the result e.g. “Single hazards” shows the single processes one by one in detail while under “Overlapping hazards” up to three processes and their overlaps can be displayed at a time, though without showing details of the processes. In the map “Number of hazards” the thematic information is further reduced to transmit in an obvious way the information how many processes overlap in which area.

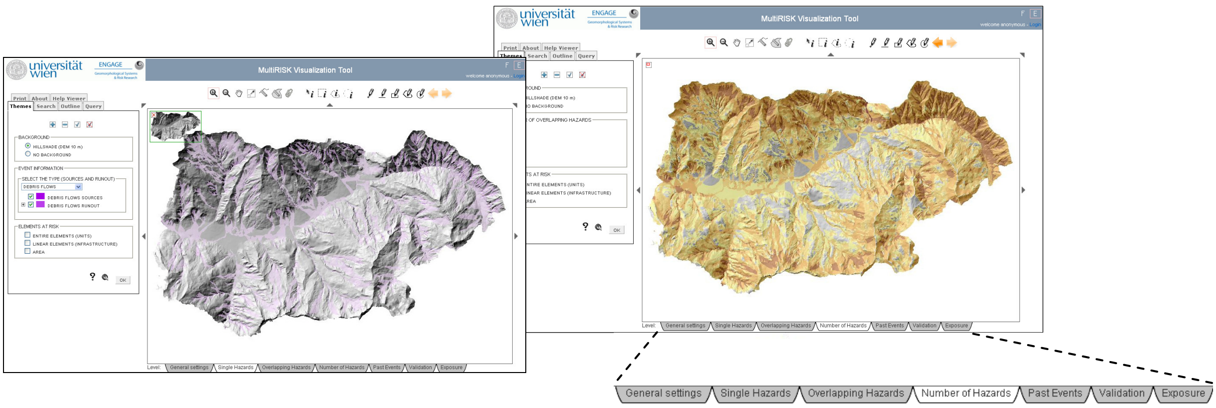

Fig. 4 Interface of the MultiRISK - Visualization Platform. Amplification of the tabs with maps/switches.

MULTIRISK – MODELING & VISUALIZATION TOOL

The capacities of the MultiRISK - platform with its two modeling and visualization tools have been designed and tested operationally for the Barcelonnette case study in the South French Alps. This region has been selected due to its comprehensive spatial data sets which are available for research projects (refer to http://omiv.osug.fr/index.html for details). In addition, a general web-based platform to visualize the available data has been developed and implemented by Frigerio et al. (2010). The available data required for the MultiRISK - platform are summarized in Tab. 1.

Tab. 1 Available geospatial data in the Barcelonnette region.

Data	Detail	Type / Scale / resolution	References
DTM		1:10,000, 10m resolution	Thiery et al. (2007); Thiery (2007)
Lithology		1:50,000, 1:2,000	Thiery et al. (2007); Thiery (2007)
Land use		1:50,000	Bordonné (2008)
Natural hazard inventories	Debris flows	Polygones	Remaître (2006)
	Shallow landslides	1:10,000	Thiery et al. (2007)
	Rock fall	Polygones	Thiery (2007), RTM (2000a)
	Snow avalanche	Polygones	MEDD (2007)
	Floods	Polygones	RTM (2000a,b, 2002, 2008)
Elements at risk	Buildings, Infrastructure (Roads, pathways), outline of settlements	Polygones, lines points	Puissant et al. (2006)

Within the MultiRISK - Visualization Tool, the general setting of the respective region can be displayed. For the Barcelonnette case study, the available settings includes a hillshade for the background, information on slope and its derivatives, on planar curvature, on lithology and on different land use types. The latter one is displayed in Fig. 5.

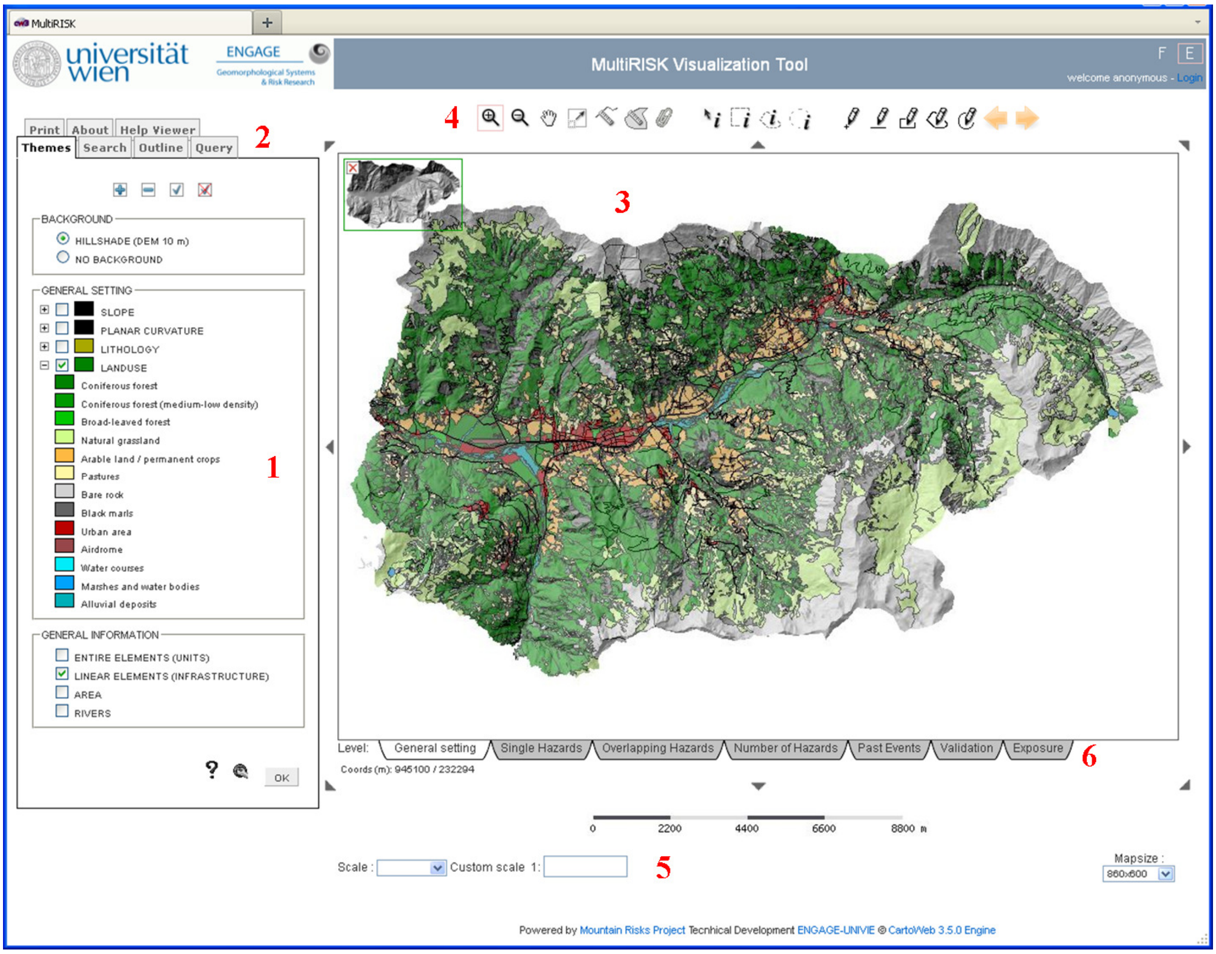

Fig. 5 The general setting of a case study region within the MultiRISK - Visualization Platform applied in the Barcelonnette Region, Southeastern France (refer to Kappes et al., (2012) for details). The selectable general settings are marked with the red number 1, the different navigations options are possible at number 2, the selected excerpts are displayed in the field number 3, the navigation options within 3 are presented at number 4, the scale can be customized at number 5, and the different thematic themes can be selected at the different tabs at number 6.

Other environmental or topographic settings could be included, if required and available. This information provides thus a background information for the more detailed hazard related information, which is displayed in Figure 6.

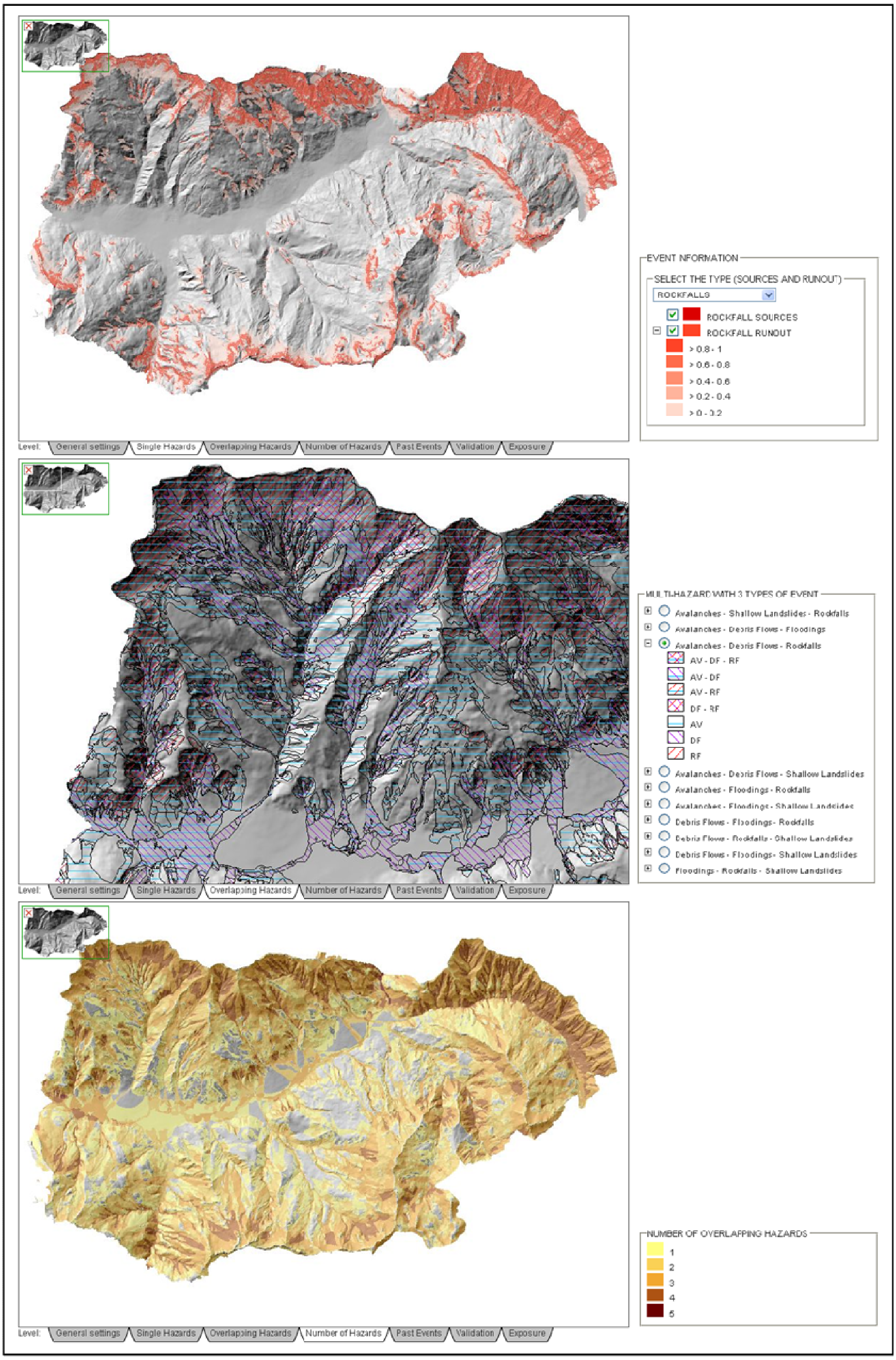

Fig. 6 The MultiRISK - Visualization Platform and different examples of outputs including single hazards (here rock falls in the upper graphic), overlapping hazards (here now avalanches, debris flows and rockfalls in the middle graphic), and the number of overlapping hazards (in the bottom graphic). Complete details are provided in Kappes et al. (2012).

The detailed information on a single hazard such as rockfall, debris flow or flood is retrievable in the second bottom tab. It is possible to select, if the runout and the deposition zones should be jointly displayed, or if it is preferred to present them separately. The respective run-out classes have been selected previously. The third bottom flag offers information on overlapping hazards. Hereby, the number of overlaps is currently limited to up to three hazards, however, it can technically also be extended more hazards. Based on experience, if more than three hazards are displayed, the resulting map is difficult to read. Therefore, a display of more than three hazards is not advisable. The fourth bottom tab overcomes the problem of readability. Here, the total number of hazards in a given location is displayed. The advantage is, that the hot spots of the locations exposed to many hazards can be easily determined, and a possible interaction can be approximated. For example, a snow avalanche might remove the forest cover and thus, the region might be more exposed to rock falls. However, the disadvantage is that it cannot be determined from this graph, which processes are involved. One needs to refer to the second or third tab to get this information. The fifth tab provides information on previous events. This seemed to be very important in particular from an applied point of view. Although the previously introduced modeling results provide important information on probable future events, the past events summarize the available records and offer evidence for decision makers and responsible parties. The sixth tab gives the result of the validation of the modeled results. Spatial distribution on values between true positives, false positives, true negatives and false negatives gives another important information on the quality of the modeled results. This procedure and the possible interpretations are given in detail by Kappes et al. (2012). Finally the exposure is presented in overlaying the elements at risk with the respective natural hazards. An example is given in Figure 7.

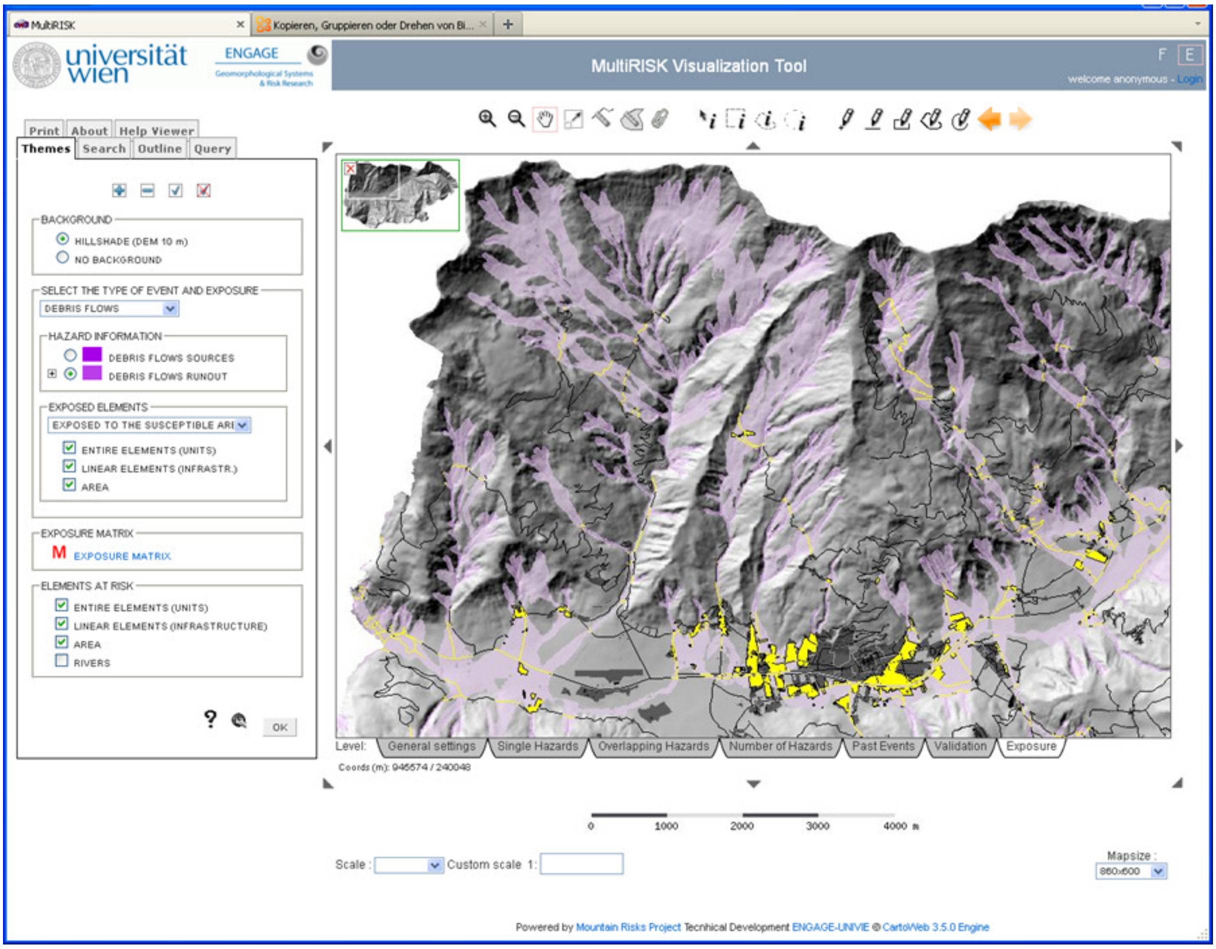

Fig. 7 The visualization of elements at risk exposure towards specific natural hazards, in the displayed modus specifically towards debris flows (for details see Kappes et al., sub.).

Indeed, the possible hot spots of the "interaction" between the elements at risk and the different natural hazards offer a unique opportunity to visualize the affected regions. Hereby, the different types of natural hazards as well as the different elements at risk can be selected. Consequently, this visualization tool offers also to approximate the possible interaction between natural hazards and planned infrastructural, industrial or residential developments.

CONCLUSIONS

Multi-hazard risk analyses pose a variety of challenges which have to be faced consciously during the elaboration of a common analysis scheme. Such a scheme is offered here as the MultiRISK - platform with its two components of the modeling tools and the visualization tools. This implementation into different tools offers additionally the possibility of rapid and user-friendly re-computation with e.g. modified input data or different parameters. Both tools allow the direct and understandable communication of the results. First tests in the study region of Barcelonnette case study have been proven the system as reliable and manageable. However, further research is indeed required with respect to the different analysis and visualization steps.

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