A COMPARATIVE ANALYSIS OF VULNERABILITY FUNCTIONS FOR USE IN MOUNTAIN HAZARD RISK MANAGEMENT

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INTRODUCTION

In natural hazards research, risk is defined as a mathematical function of (1) the probability of occurrence of a hazardous process, and (2) the assessment of the related extent of damage, defined by the value of elements at risk exposed and their physical vulnerability. Until now, various works have been undertaken to determine vulnerability values for objects exposed to hazard processes, in particular with respect to torrent processes and snow avalanches. Yet, many studies only provide rough estimates for vulnerability values based on proxies for process intensities. However, the vulnerability values proposed in the literature show a high range, in particular with respect to medium and high process intensities. In our study, we compare vulnerability functions for torrent processes derived from studies in test sites located in the European Alps and in Taiwan. Based on this comparison we deduce needs for future research in order to enhance mountain hazard risk management with a particular focus on the question of vulnerability on a catchment scale.

METHOD

The method was based on an ex-post approach examining recent incidences were information on both, the height of loss and the documentation of the hazardous event, were available. Vulnerability was quantified using an economic approach by establishing a quotient between the loss and the reinstatement value of every individual element at risk exposed. In a second set of calculations, this ratio obtained for every individual element at risk was attributed to the respective torrent process intensities; deposition heights which were used as a proxy for process intensity (Fuchs et al., 2007). The data were analysed in a spatially explicit way by using GIS. As a result, scatterplots were developed linking process intensities to vulnerability values. These data were analysed using regression approaches in order to develop vulnerability functions which served as a proxy for the structural resistance of buildings with respect to the torrent processes studied. Additionally, uncertainties were quantified by calculating confidence bands with different confidence levels (90, 95 and 99 %). Following this approach of applied research, we compared vulnerability functions from individual torrent fans in Austria and Italy, and from catchments in Taiwan. These functions were further compared to semi-quantitative and qualitative information published (Fuchs and Heiss, 2008).

RESULTS

The results from the test sites in Austria and Italy clearly indicate a dependence of object vulnerability on process intensities. Low intensities and high intensities show a relatively small range in the results. However, with respect to medium intensities, the range is considerably high since the amount of damage is dependent on whether or not the damaging process affected the interior of buildings. The derived vulnerability values show a similar pattern and the presented vulnerability curves show a similar shape, even if the individual best-fitting functions differ. Results from the test sites in Taiwan principally followed the same functional type. In contrast to the European data, however, they were characterised by a considerable range over the entire dataset. One reason therefore is a different accounting method for damage when information on losses is collected after an event. Hence,

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buildings that had not been entirely destroyed were accounted as being totally lost in order to get the compensation necessary for a reconstruction.
Vulnerability is highly dependent on the construction material used for exposed elements at risk. The buildings studied within the European test sites were constructed by using brick masonry and concrete, a typical construction design in post-1950s building craft in alpine countries. Data from the Taiwanese test sites had shown that damage to buildings constructed from bricks is higher in numbers than damage to buildings constructed from (partly reinforced) concrete. However, if the range of vulnerability values is taken into consideration, the values are already highly variable for process intensities of 1 m (brick buildings) and 1.5 m (concrete buildings).

DISCUSSION

If risk analyses are carried out with respect to the probable maximum loss, a vulnerability value of 1 will generally be assigned to exposed elements at risk. However, such solutions are not very targeted with respect to a better understanding of the vulnerability of elements at risk to torrent events. A general strategy in determining vulnerability of elements at risk to specific events was still missing. Until now, vulnerability models are mainly based on plausibility issues, expert knowledge, conceptual approaches, and assessments of historical data. Hence, they are for the most part based on qualitative statements on observed damage.
To overcome this gap, a spatially explicit and economic approach was used to model the vulnerability of buildings exposed to torrent processes. Information about process intensities, monetary loss and reconstruction values provided the input to derive vulnerability functions for fluvial sediment transport processes and debris flows in mountain torrents in the European Alps and in Taiwan.
The results of this study have shown that fluvial sediment transport processes due to torrent events cause similar economic damage than damage related to debris flow processes. Hence, the general assumption that fluvial sediment transport processes are less destructive than debris flow processes (Hungr et al., 2001) cannot be confirmed by the present study.
In general, the test sites resulted in a similar functional relationship of process intensities and damage ratio, which was shown in a respective vulnerability function. Even if the range in the results was considerable, the comparative assessment provided insight in an enhanced understanding of vulnerability to torrent events. If compared to previous studies published from the European Alps, the quantitative approach clearly resulted in comparable and reproducible results, which are important for any ex-ante approach as well as for a conversion of results to other test sites. Nevertheless, further research is needed with respect to a spatial and temporal resolution of vulnerability, since in the European Alps, a major trigger can be attributed to intense but local and therefore spatially limited thunderstorms, leading to either debris flows or fluvial sediment transport of moderate magnitudes, while the trigger in Taiwan is of typhoon type with a regional and therefore less-spatially limited extent leading to large-scale events.

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Keywords: mountain hazards, vulnerability, risk management