THE CONCEPT OF VULNERABILITY – EVIDENCE FROM AN APPLICATION TO DEBRIS FLOWS

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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 damage potential and the vulnerability according to the intensity of the hazard process. Hence, vulnerability is considered as a function of given process intensities towards physical structures; and is therefore related to the susceptibility of elements at risk. Thus, vulnerability – often referred to as 'technical' or 'physical' vulnerability in this context – is defined as the expected degree of loss for an element at risk as a consequence of a certain event.
Until now, only little work has been done to determine vulnerability values for objects exposed to torrent processes, in particular to debris flow hazards. Furthermore, relevant studies only provide rough estimates for vulnerability values based on process intensities. A broad validation of those estimates is – for most of the studies – outstanding. Moreover, the vulnerability values proposed in the literature show a high range, in particular with respect to medium and high process intensities.

METHOD

To close this gap, data from a test site in Austria was used to analyse and assess the vulnerability of buildings to debris flows.
The process characteristics in the accumulation area were determined on the basis of the process documentation carried out subsequently after the event by the Austrian Torrent and Avalanche Control Service (WLV), a federal institution operating throughout Austria to protect the population from torrents, erosion and avalanches. These data were supplemented by the analysis of data gathered from a re-calculation of the event, above all a reconstruction of the accumulation heights on the fan. As a result, different process intensities were determined for the event, dividing the accumulation area into areas with different process severity.
The elements at risk – which were defined as those buildings within the test site located on the fan – were analysed with respect to their spatial location and extension using GIS. The size of the buildings was recorded from digital datasets of the communality administration and provided the basis for a monetary evaluation of the reconstruction values. These values were calculated using the volume of the buildings and average prices per cubic metre according to the type of building.
The losses due to the studied event were collected using information on the extent of damage from the federal authorities. For this study, these data were adjusted to inflation and attributed to the information on every single element at risk using GIS.
Vulnerability was defined by the quotient between loss and individual reinstatement value for each element at risk in the test site. The vulnerability value obtained for every single building in the test site was attributed to the process intensities of the studied event. As a result, a vulnerability function was developed, linking process intensities to object vulnerability values. Consequently, this vulnerability function is a proxy for structural resistance of buildings with

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respect to dynamic debris flow impacts, and can thus be used for a spatially explicit assessment of debris flow susceptibly.

RESULTS

The results from the test sites clearly indicate a dependence of object vulnerability on process intensities. In detail, the data do not suggest a linear increase in vulnerability, the relationship between debris flow intensity x and vulnerability y was found to fit best to the data by a second order polynomial function:

$$y = 0.11x^2 - 0.02x$$

Low intensities and high intensities show a relatively small range in the results. However, with respect to medium intensities, the amount of damage is dependent on whether or not the damaging process affected the interior of buildings. A sensitivity analysis was carried out to evaluate the results. Based on the studies, vulnerability values between 0.02 and 0.45 are suggested for different debris flows intensities, see Table 1.

Tab. 1 Vulnerability values for different debris flow intensity classes

Intensity class	Spread	Mean
0.5 m	0.00 – 0.07	0.02
1.0 m	0.02 – 0.04	0.03
1.5 m	0.00 – 0.33	0.21
2.0 m	0.34 – 0.53	0.45
2.5 m	0.52	-

CONCLUSIONS

The presented method followed a spatial approach, and was based on process intensities, volumes of elements at risk and average reconstruction values in dependence of the surface area on an object basis. Nevertheless, since vulnerability was defined using an actuarial approach, the relation between reconstruction values and losses principally allows a wider application in regions with different economic background. Since the analysis was based on process intensities and is thus independent from recurrence intervals, not only the risk resulting from design events can be calculated but also every other event with a different magnitude and frequency.
Vulnerability is highly dependent on the construction material used for exposed elements at risk. The buildings studied within the test site were constructed by using brick masonry and concrete, a typical construction design in post-1950s building craft in alpine countries. Consequently, the presented intensity-vulnerability relationship is applicable to this mixed construction type within European mountains. However, a wider application of the presented method to additional test sites would allow for further improvement of the results and would support an enhanced standardisation of the vulnerability function.

Keywords: vulnerability, intensity-loss relationship, torrent events, Austria