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Indicator-based model to assess vulnerability to landslides in urban areas. Case study of Husi city (Eastern Romania)

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In the last three or four decades, vulnerability evolved from physical fragility meanings to a more complex concept, being a key element of risk assessment. In landslide risk assessment, there are a large series of studies regarding landslide hazard, but far fewer researches focusing on vulnerability measurement. Furthermore, there is still no unitary understanding on the methodological framework, neither any internationally agreed standard for landslide vulnerability measurements. The omnipresent common element is the existence of elements at risk, but while some approaches are limited to exposure, other focus on the degree of losses (human injuries, material damages and monetary losses, structural dysfunctions etc.). These losses are differently assessed using both absolute and relative values on qualitative or quantitative scales and they are differently integrated to provide a final vulnerability value.

This study aims to assess vulnerability to landslides at local level using an indicator-based model applied to urban areas and tested for Husi town (Eastern Romania). The study region is characterized by permeable and impermeable alternating sedimentary rocks, monoclinal geological structure and hilly relief with impressive cuestas, continental temperate climate, and precipitation of about 500 mm/year, rising to 700 m and even more in some rainy years. The town is a middle size one (25000 inhabitants) and it had an ascending evolution in the last centuries, followed by an increasing human pressure on lands.

Methodologically, the first step was to assess the landslide susceptibility and to identify in this way those regions within which any asset would be exposed to landslide hazards. Landslide susceptibility was assessed using the logistic regression approach, taking into account several quantitative and qualitative factors (elements of geology, morphometry, rainfall, land use etc.). The spatial background consisted in the Digital Elevation Model and all derived maps (slope, aspect, shading), realized based on the topographical plans and maps (1:1000, 1:5000).

The second step was to realize the spatial inventory of elements at risk (vector format), based on the General Urban Plan (1:5000), the orthorectified aerial images (2009, resolution: 0.5 meters) and field investigations. All elements have been classified using attribute databases: residential buildings (single or multiple dwellings), other buildings according to their functionality, main and secondary roads, special transport network etc. Data about population have been added in order to assess the intrinsic value of each element and the number of potentially affected peoples. The study also took into account issues as preparedness and preventive measures (risk prevention plans, reinforcing structures, draining wells etc.), coping ability (network geometry and connectivity, emergency services accessibility) and recovering capacity (e.g. the existence of insurance policies).

According to their importance and functionality, a distinct rank (ri … rn) was assigned to each element at risk (i1…in) showing the level of vulnerability. The rank values were assigned mainly on the expert knowledge and they range from 1 (limited damages, no affected people) to 5 (several households and people affected, dysfunctions in the urban system). The vulnerability index (Vi) was obtained combining the rank with the role of vulnerability factors (Fi), according to their degree of influence: the number of people that would be affected, the potential material and economic damages, the relationship with the neighboring exposed elements, the existence of the preventing, coping and recovering measures etc. Thus, the general equation of vulnerability has the form of weighted geometric mean: Vi=ri•Fi = ri•(w1F1 • w2F2 • … • wmFm). It must be noted that the weighting coefficients (wi) have subunitary or supraunitary value according to their role in diminishing or increasing the vulnerability level. The general vulnerability index (GVI) was obtained through a final transformation that was done to limit the spread of variation between zero (minimum vulnerability) and one (maximum vulnerability): GVIi = Vi/Vmax.

In this form, the elements at risk are individually inventoried and spatialized in vector format as points, lines, polygons, each one having its own vulnerability value, but the results can be used only at the precise local level (both by practitioners and decision makers). To allow a more profound interpretation, the general vulnerability index was spatialized in two distinct ways: (1) creating a raster with a standard pixel size (e.g. 20 x 20 m, 50 x 50 m) and calculating the average vulnerability of the exposed elements in each pixel; (2) choosing a interpolation method (e.g. krigging) that would allow to integrate the spatial autocorrelation of the elements at risk and to obtain an output raster at the same resolution with the susceptibility map and a further risk assessment.