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GEOMORPHOLOGIC VULNERABILITY OF SLOPES IN THE URBAN PLANNING OF TÂRGU MUREȘ MUNICIPALITY

CRISTIAN TIBERIU TOGĂNEL[1], IOAN-AUREL IRIMUȘ[1], SANDA ROȘCA[1*], GEORGE RUS[1]

ABSTRACT. – Geomorphologic Vulnerability of Slopes in the Urban Planning of Târgu Mureș Municipality. The identification of the geomorphologic vulnerability of a territory is a very important stage in the process of urban planning. Târgu Mureș municipality has extended its built-up area in the last few years independently of the restrictions which should be imposed in order to avoid the situation of building in areas with a high probability of landslide occurrence. As a consequence, the present study classified the built-up area of Târgu Mureș in probability classes for landslide occurrence according to the Governmental Order 447/2003 and using GIS technology which facilitates such complex analyses. Specialised data was collected using geomorphologic mapping which captured the active slope processes. These were eventually used for validating the final results.

Keywords: *active landslides, GIS modelling, H.G. model*

1. INTRODUCTION

Târgu Mureș municipality has 144806 inhabitants and it is a medium-sized city in the Central Region of Romania, the county seat of Mureș County, located in the Transylvanian Depression, in the middle part of Mureș River (Fig. 1). Due to its geographical position and its economic development, it is the main polarising centre of the Transylvanian Plain, representing a second–rank urban centre in the regional system (*PUG Târgu Mureș*, 1998).

The fact that the Târgu Mureș municipality is included among the areas with a medium and high probability of landslide occurrence has already been mentioned in various studies which have classified the Transylvanian Depression

[1] *Babeș-Bolyai University, Faculty of Geography, Department of Technical and Physical Geography, Clinicilor Street, 400006, Cluj-Napoca*
* *Corresponding author: sanda.rosca@ubbcluj.ro*

(Mac and Tudoran, 1977, Surdeanu et al., 1998, Petrea et al., 2014) or the entire national territory (Bălteanu and Micu, 2009) in landslide probability classes.

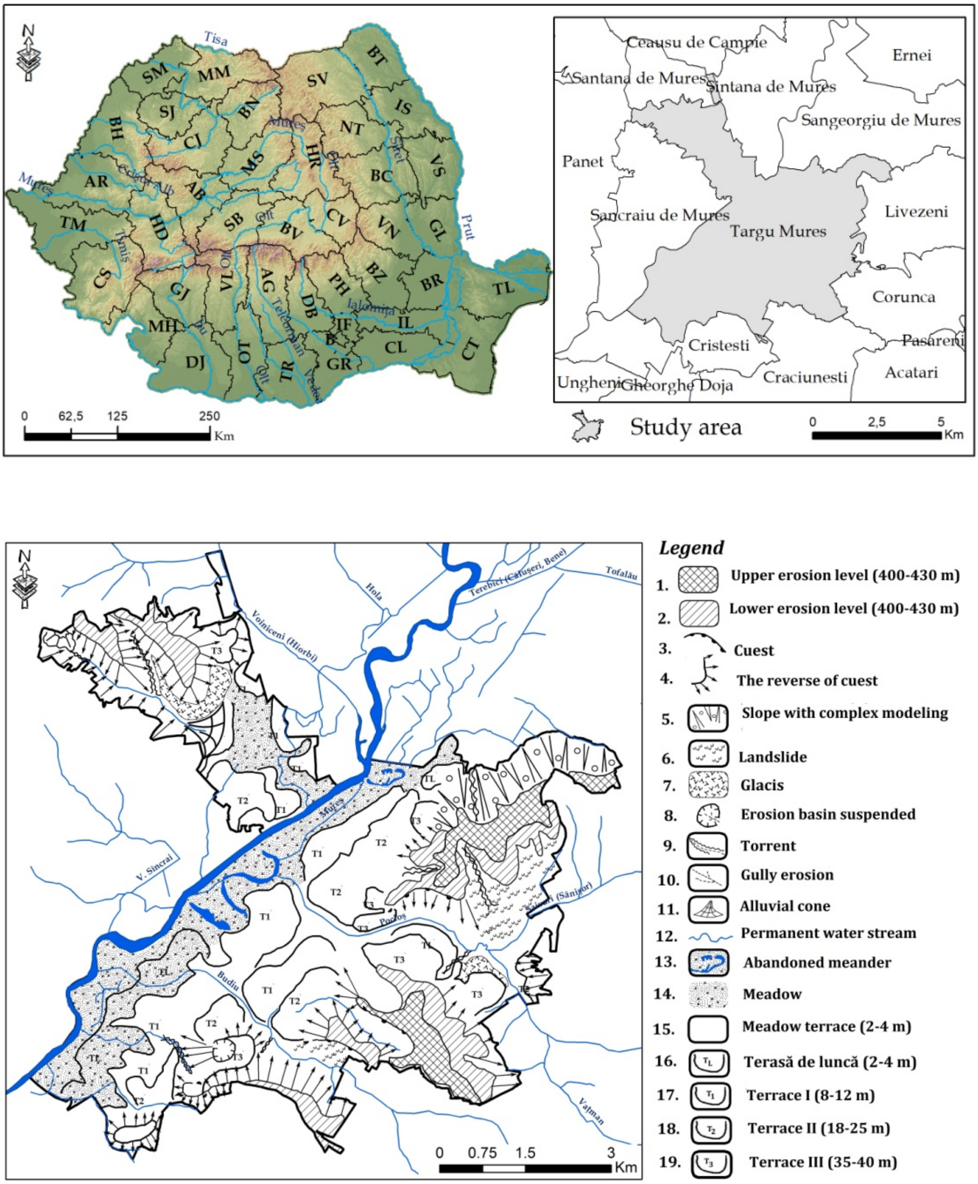


Fig. 1. Geographical position of the study area and the geomorphologic map

The areas which are known to be affected by landslide occurrence, either triggered by natural factors (high precipitation values, strong erosion) or by artificial factors (overloading of the slopes, vibrations, improper land management etc.), are represented by territories of various sizes such as Corneşti Plateau, Budiu Hill (Dâmbu Pietros neighbourhood), Maşini de Calcul area (Tudor Vladimirescu neighbourhood) (*PUG Târgu Mureş*, 1998), but especially in the dome area of Corunca (Irimuş, 1998). Thus, according to the studies made before 2001, the number of households which could be affected by landslides was 96, and the number of people was 278 (*PUG Târgu Mureş*, 1998). The use of GIS technology in order to identify the probability of landslide occurrence is based on the variable factors which cause and trigger landslides and which can be included in quantitative and qualitative models for determining the probability of landslide occurrence, previous studies having good results in this respect (Bilaşco et al., 2011, Marian et al., 2015, Moldovan et al., 2015, Colniţă et al., 2016, Irimuş et al., 2017).

Determining the geomorphologic vulnerability of the slopes as a consequence of the probability of landslide occurrence is an extremely important stage in the spatial planning of the study area. This is done as a rational operation put into practice as public works and as a control factor over various phenomena (Benedek, 2004, Irimus, et. al., 2005, Surd et al., 2005). Thus, the macro and micro scale approach of the present study requires a spatial zonation using qualitative and quantitative criteria (Benedek and Man, 2016).

2. MATERIALS AND METHODS

By analysing the topographic maps and the satellite images of the study area, we have identified several areas affected by shallow and deep landslides, areas which were marked on the geomorphologic map (Fig. 1) and were studied in the field (Fig. 2). As a result, we identified the active, contemporary geomorphologic processes, the stabilised and the partially stabilised ones, as well as the areas affected by Pleistocene geomorphologic processes (the landslides at Corunca).

In order to implement the model of probability identification for landslide occurrence, according to the norms provided by the Governmental Order 447/2003, a cartographic database was created including the slope angle map, the digital elevation model, the precipitation grid, the hydrographical network, elements of the built-up area etc. Similar studies from national, regional and county study areas or at the level of administrative units, using GIS technology and the methodological norms provided by the Governmental Order 447/2003, reflect a good capacity of the model for estimating the probability classes of landslide occurrence (Roşca, 2015).

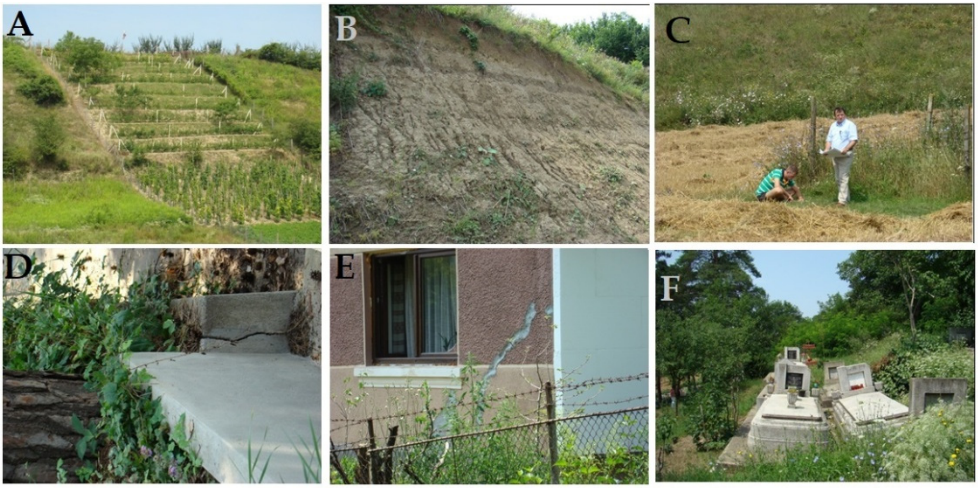


Fig. 2. Present geomorphologic processes in the study area

Using the special techniques of mapping and the GIS spatial analysis, the maps of landslide hazard were generated (the maps of lithological, geomorphologic, structural, hydrologic and climatic, hydrogeological, seismic, forest and anthropogenic coefficients).

In order to identify the elements of the built-up area which are exposed to landslide risk, the buildings and the transportation network were mapped using recent satellite images (the software Google Earth). Thus, 17389 buildings and 528 km of road were identified (including all the road categories in the administrative unit of Târgu Mures), these elements being used in order to create the map of the anthropogenic coefficient (Kh).

In order to generate the map of the lithological coefficient (Ka), the geological map with the scale of 1:200,000 had to be digitised.

The map of the geomorphologic coefficient (Kb) was generated using the Digital Elevation Model with a 10 m resolution, as well as the map of the slope angle which enabled the classification into probability categories according to the intervals stated in the Governmental Order 447/2003.

The hydrologic and climatic coefficient (Kd) was generated using the hydrological network and the precipitation grid (which was determined by using the equation of the correlation between the precipitation amount from the weather stations located in the Transylvania Depression and their altitude).

The 2012 *Corine Land Cover* database was used to create the land use map which was used in its turn to generate the map of the forest coefficient (Kg), the focus being laid on the areas with deciduous forests, fir and mixed forests.

The hazard coefficient (Km) was determined using the formula (1):

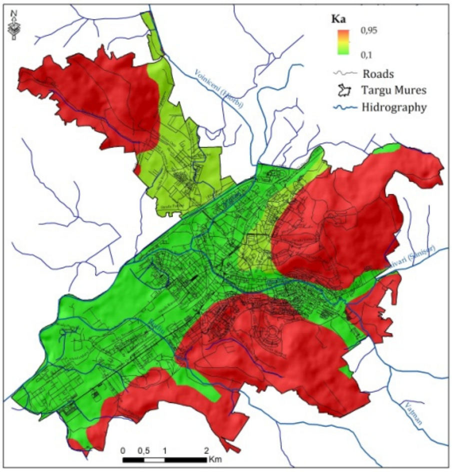
$$Km = \sqrt{\frac{K_a * K_b}{6} * \ K_c + K_d + \ K_e \ + K_f + \ K_g + K_h},$$

Where: K_a – *Lithological coefficient, Kb – Geomorphologic coefficient, Kc – Structural coefficient, Kd – Hydrologic and climatic coefficient, Ke – Hydrogeologic coefficient, Kf – Seismic coefficient, Kg –Forest coefficient, Kh – Anthropogenic coefficient, Km – Average hazard coefficient.*

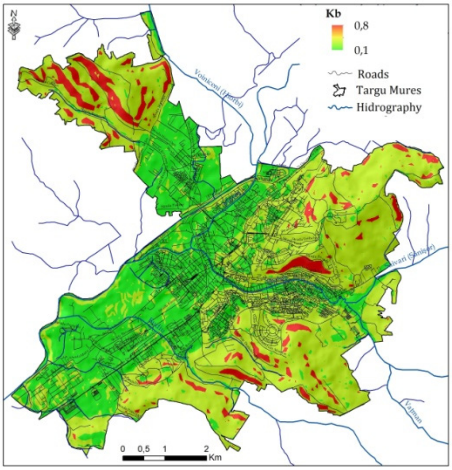
3. RESULTS AND DISCUSSION

By applying the techniques of spatial analysis, interpolation and reclassification, a database of the coefficients (Ka...Kh) was generated using a 10 m resolution, similar to the DEM. As a result, the highest probability for landslide occurrence characterises the lithologic coefficient represented by lithologic classes like gravel, sand, debris (pn and qp2/3) and marly clays (vh+bs1), the geomorphologic coefficient (areas characterised by slope values that are larger than 12°), values of the annual average precipitation larger than 700 mm/year, areas with a very low coefficient of forest coverage as well as slopes with a high density of roads and slopes overloaded with constructions.

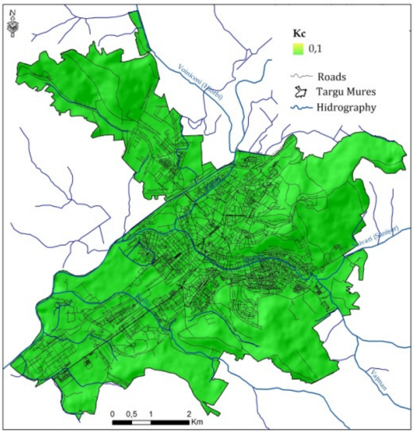
The equation used for calculating the average hazard coefficient (Km) was implemented to generate the final grid with values ranging between 0.046 – 0.679 (Fig. 3).



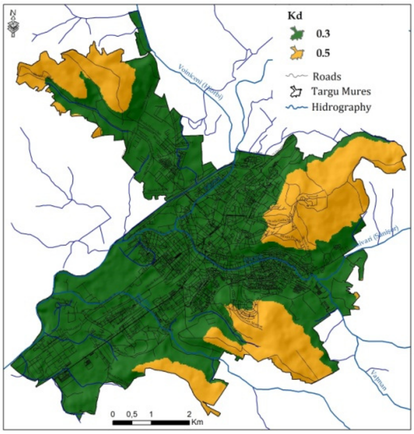
Ka- lithologic coefficient



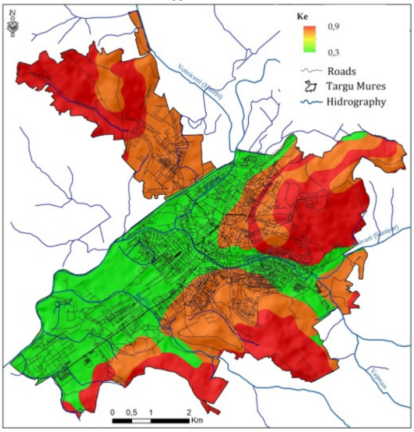
Kb- geomorphologic coefficient



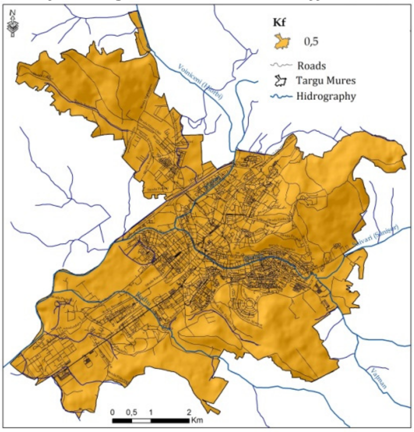
Kc- structural coefficient



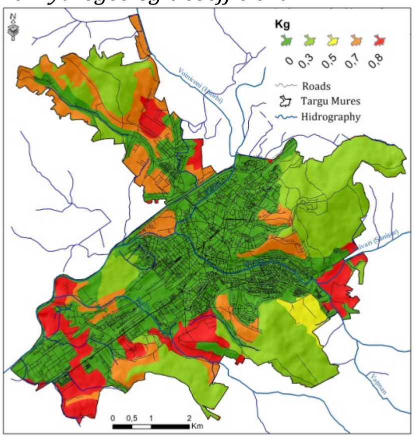
Kd- hydrologic and climatic coefficient



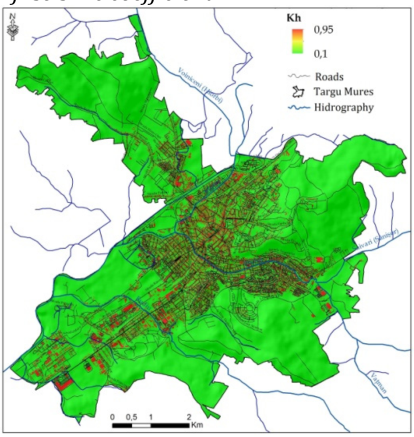
Ke- hydrogeologic coefficient



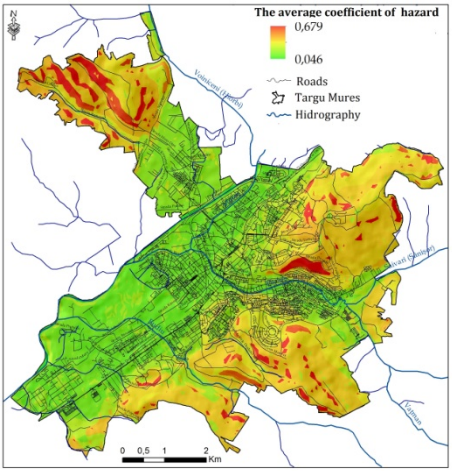
Kf- seismic coefficient



Kg – forest coefficient



Kh – anthropogenic coefficient



Km-average hazard coefficient

Fig. 3. Database of the hazard coefficients for landslides

The areas with medium-high and high probability for landslide occurrence have a large extension in Unirii neighbourhood (especially on the lands used as orchards and agricultural land), Gheorghe Marinescu, Tudor Vladimirescu, Belvedere neighbourhoods, as well as Mureșeni and Dâmbu Rotund (Fig. 4).

In the administrative unit of Târgu Mureș, one notices that for 21.2 km^2 (which is 43.4% of the entire study area) the medium probability class is present (with an average hazard coefficient between 0.10-0.30), but for 41% of the territory the corresponding probability class is medium-high ($0.3<Km<0.5$) (an area of 17.6 km^2) and high probability ($0.5<Km<0.68$) for 2.4 km^2 (Table 1).

Table 1. Percentage distribution of probability classes for landslide occurrence

Probability class	Area		Buildings	
	km^2	%	Number	%
Low (0.04 – 0.1)	7.8	15.9	3543	20.38
Medium (0.10 – 0.3)	21.2	43.4	8765	50.41
Medium-high (0.3 – 0.5)	17.6	35.9	5054	29.07
High (0.5 – 0.68)	2.4	4.9	27	0.12

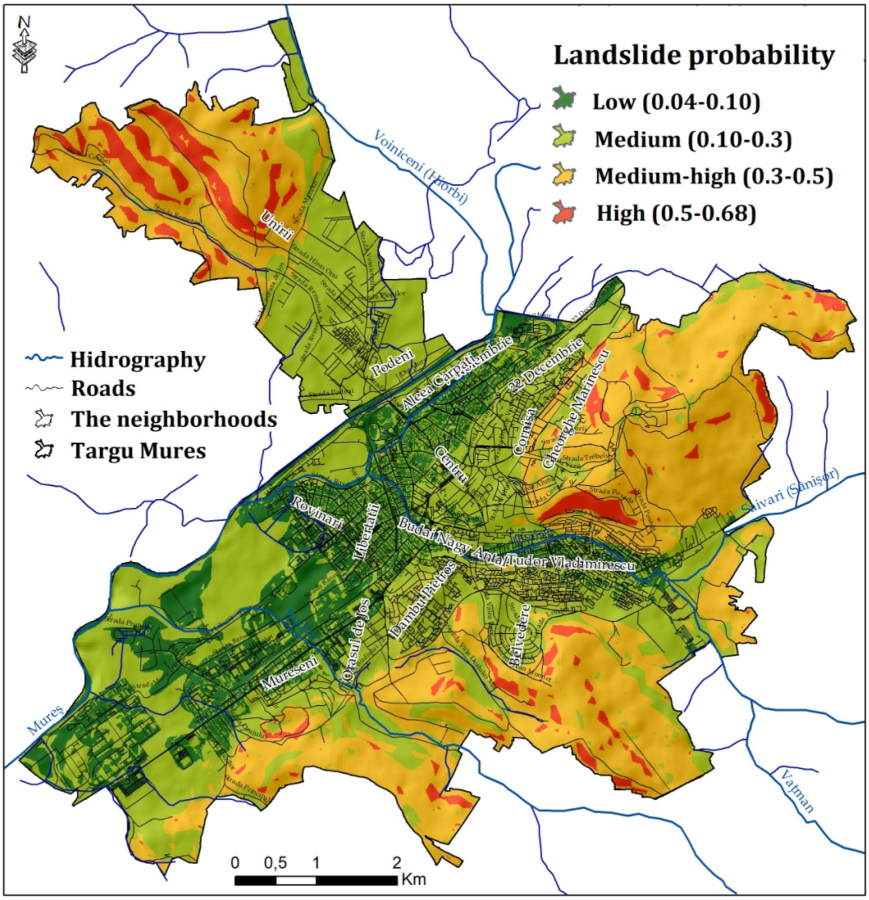


Fig. 4. Probability map of landslide occurrence

Using the statistical tools supplied by GIS software, we were able to classify each construction in a probability class of landslide occurrence, the total of buildings being 17389. One can notice the fact that 8765 buildings (representing 50.41% of the total) are located in areas with a medium probability of landslide occurrence and they are characterized by a value of the average hazard coefficient in the interval 0.10-0.30.

The buildings located on a territory with a medium-high probability of landslide occurrence represent less than 29.07% because the constructions located in unsuitable areas, characterized by a high probability of landslide occurrence, represent 27% of the total (Table 1).

The latter are situated on Negoiu and Posada streets (in Tudor Vladimirescu neighbourhood), but also on Pădurii and Răsăritului streets (in Gheorghe Marinescu neighbourhood). These areas were also highlighted by the field work which enabled the geomorphologic mapping of the area, therefore the model used in this study is indicated to be highly representative for the study area.

4. CONCLUSIONS

GIS technology was used in the present study in order to classify the administrative unit of the Târgu Mureș municipality in probability classes for landslide occurrence, taking into consideration the methodological norms for the setting up of the contents of landslide risk maps (Government Order 447/2003) and the guide for making landslide risk maps to ensure the stability of constructions (Indicative GT-019-98).

As a result, the study identified 4.9% of the administrative unit of Târgu Mureș in the class of high probability of landslide occurrence as a result of the presence of causing and triggering factors (these territories are characterised by values of the average hazard coefficient ranging between 0.5 – 0.68).

The analysis of the spatial distribution of buildings in probability classes of landslide occurrence highlights 27 buildings situated in areas with dynamically active potential, their effects being noticed also in the field work stage.

This methodological endeavour was based on GIS specific techniques and methodologies, as well as the monitoring and mapping of the active landslides and their probability of occurrence. All these were performed in order to reduce the negative specific consequences and to establish prevention and mitigation measures for material losses through authorising the conditions required for executing new constructions in these areas.

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