

LANDSLIDE SUSCEPTIBILITY ASSESSMENT IN THE IRICĂU GLACIS (BAIA MARE CITY, ROMANIA)

Daniel NĂSUI^{1,2}, Ana PETREUȘ²

¹PhD Student, Department of Geography, West University of Timisoara, Blvd. V. Pârvan, 4, Timișoara, nasui@ubm.ro

²Technical University of Cluj Napoca, North University Center of Baia Mare, V. Babeș, 62/A, ana.petreus@gmail.com

Abstract: The Iricău Glacis is one of the most affected areas by landslides from the Baia Mare region. The problem increases as in the last twenty years the residential areas expanded into the region, accelerating the present landslides or generating new ones. The proposed methodology for estimating landslide susceptibility is based on a suitability approach, in which the slope, curvature and the land use factors give the best results, as most of the present landslides validate the custom built model. More than 80% of the active landslides fitted the average-high and high susceptibility classes determined through modeling. Its suitability for this case study shows that the adaptation of well-known landslide assessment models to the local conditions can give better results than applying the actual models.

Keywords: landslides, susceptibility, GIS, Iricău, glacis, model

1. INTRODUCTION

When considering landslides as natural hazards, spatial analysis is being often used in mapping susceptibility, a measure of an area's predisposition to landslides, based on the presence of some known causing factors or on the history of events which affected a particular slope (Crozier & Glade, 2005).

The available methods to assess the landslide susceptibility can be divided into qualitative (mainly heuristic methods) and quantitative approaches, mainly deterministic and statistic methods (Van Westen, 2004). The qualitative approach uses subjective estimations based on landslide inventory (Guzzetti et al., 2012), but can also contain errors given by the author's subjectivity and knowledge (Fell et al., 2008).

Because of numerous areas affected by landslides, the Government of Romania issued the Decree 447/2003 which establishes the methodology for the elaboration and content of natural landslides hazard maps with application guidelines published in Monitorul Oficial 305 on the 7th of May 2003.

In various situations, this methodology allows some conclusive results, even though it is regarded as not so efficient by many specialists because the mark of some variables (lithological, climatic and

hydrogeological) imposes an amount of subjectivity which derives not only from the different formation of the applicants but also from the deficient types, and scales of the maps and available data for different regions of the country (Petrea et al., 2014).

Combining spatial data by means of GIS techniques allows the production of a multitude of models. However, choosing the most appropriate one cannot be accurately done without the experienced opinions of geomorphologists and geologists who know the real behavior of the natural process (Măguț et al., 2012).

Non-topographic variables such as vegetation type are equally important GIS inputs to modelling the location of shallow landsliding (Pike & Sobieszczyk, 2008).

2. STUDY AREA

The Iricău Glacis is located in the north-eastern part of Romania, in the western part of the Maramureș County (Fig. 1). The glacis is formed at the contact between the volcanic Iricău Mountain and the Baia Mare Depression, covering an area of only 5.29 km².

Altitudes range from 200m a.s.l. in the south to 440m a.s.l. in the north of the glacis. Most of the area is composed by sedimentary rocks (clay, marl,

gravel), while the slope varies from 0° to 35°, thus presenting proper conditions for landslides.

Furthermore, the expansion of the Baia Mare City's residential areas into to glacis in the past 20 years due to space limitations increased the number of landslides throughout the area. The residential areas cover more than 15% of the entire region, and it's continually expanding, making the landslide issue a costly risk for the area inhabitants in regards to the built environment.

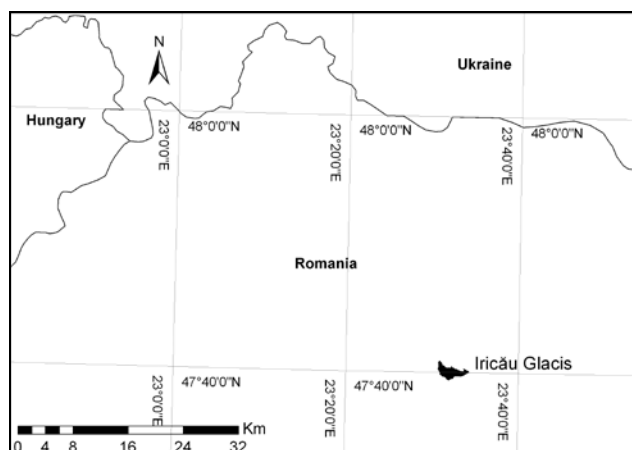


Figure 1. Location of the study area

3. DATA AND METHODOLOGY

Mapping past and recent slope movements, together with the identification of preparatory factors of slope instability are the keys in predicting future landslides (Carrara et al., 1998)

The data used in the analysis of landslide susceptibility was derived from several sources (Table 1).

Table 1. The GIS Database

Data type	Layers	GIS data type	Scale / Resolution
Filed data	Areas affected by landslides	GPS	0.5m
DEM	Slope angle	Grid	10m
	Profile curvature	Grid	10m
	Plan curvature	Grid	10m
Map data	Topographic map	Line / point	1:5.000
Aerial images	Land use	Polygons	0.5m

The landslide susceptibility map was produced by applying a combined methodology. At first, the Romanian methodology described in the Decree 447/2003, for landslide susceptibility assessment method was applied. It takes into

account eight factors, including petrography, slope, rock structure, precipitation, hydrogeology, seismic factor, forest cover and anthropogenic factor. Because the homogeneity of most of these factors (petrography based, precipitation, and seismic factor) the results were not as conclusive as expected.

The well-known SHALSTAB (Shallow Stability) model (Montgomery & Dietrich, 1994) and SMORPH (Slope Morphology) model (Shaw & Johnson, 1995) were also applied with inconclusive results due to the lack of land use cover from those models structures.

The proposed methodology follows the equation used by the Romanian system with the discount of the homogenous factors and the addition of the profile and plan curvature used by the SHALSTAB and SMORPH models. The calculated factors taken into account are included in the following formula (1):

$$Km = \sqrt{\frac{Ka * Kb}{2} * (Kc + Kd)} \quad (1)$$

Km – Probability coefficient

Ka – slope factor

Kb – land use factor

Kc – profile curvature

Kd – plan curvature

All these factors have a range of values from 0 to 1, where 1 represents the highest probability (100%) and 0 the lowest (0%).

4. RESULTS

The slope angle is one of the most important factors involved in landslide genesis and evolution (Arghiş et al., 2013).

Table 2. Computed values for the slope angle

Code	Parameter	Value	Probability	Intervals
Ka	Slope angle	0	Almost null	<3°
		<0,10	Low	3,1 - 7°
		0,11 – 0,30	Average	7,1 - 12°
		0,31 – 0,50	Average High	12,1 - 18°
		0,51 – 0,80	High	18,1 - 25°
		>0,80	Very high	>25°

The slope angle chosen intervals used in table 2 are the most suitable ones for this case study. The resulting map (Fig. 2) shows high values of probability in the northern and center parts of the glacis, with lower values being present in the south and west.

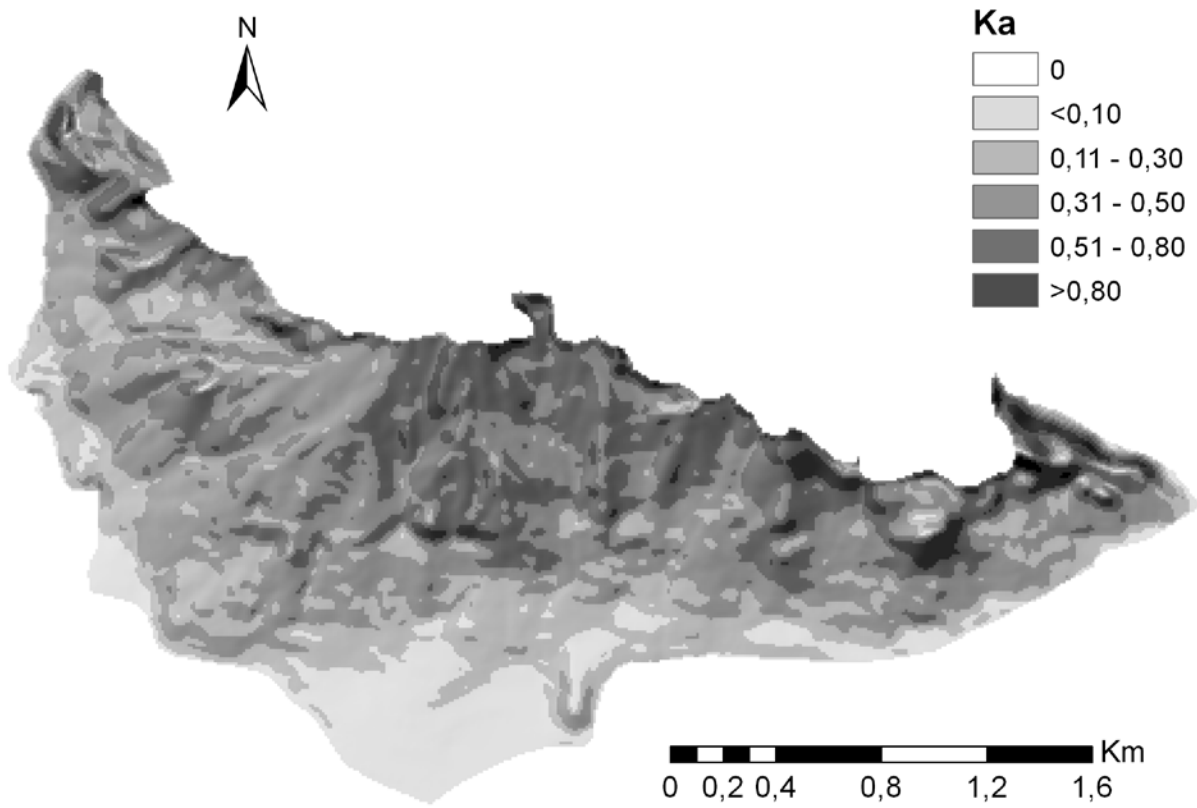


Figure 2. Distribution of the Ka factor (slope)

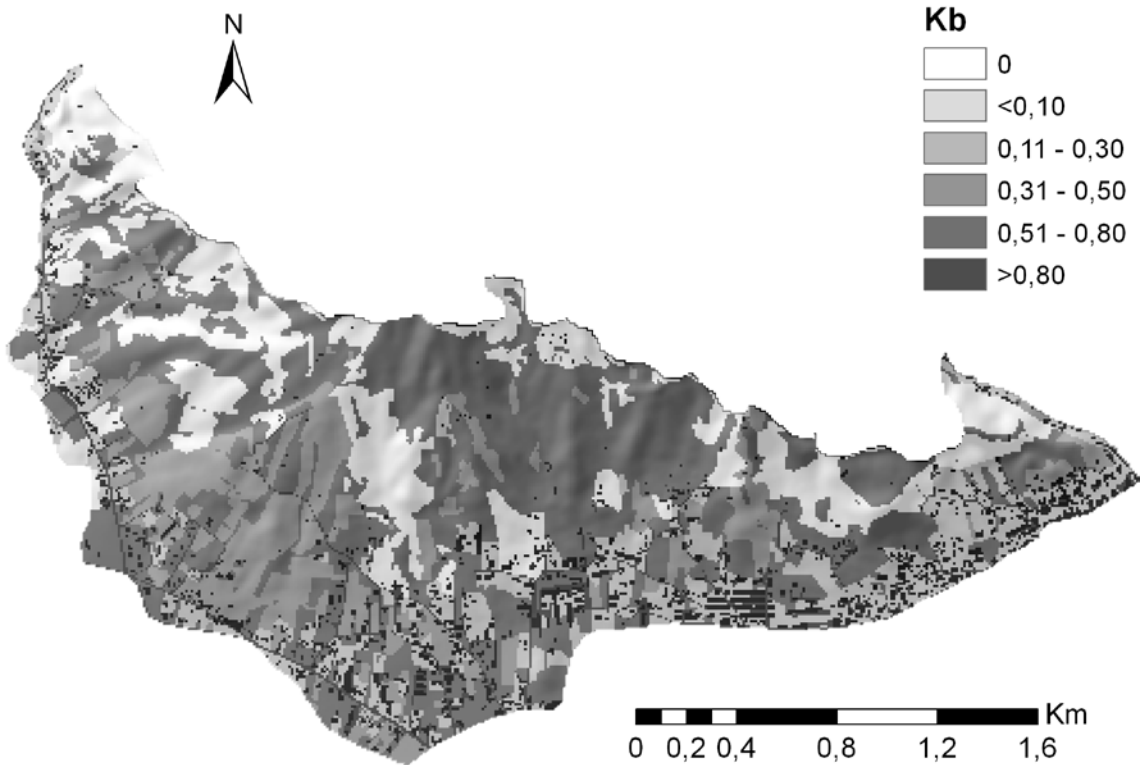


Figure 3. Distribution of the Kb factor (land use)

The land use cover (Table 3) factor was derived from the digitized aerial images, with high resolution, for identifying every building or road that

can generate mass or vibrations thus triggering a landslide event.

Table 3. Computed values for the land use cover

Code	Parameter	Value	Probability	Land use
Kb	Land use cover	0	Almost null	Forest
		<0,10	Low	Garden
		0,11 – 0,30	Average	Orchard
		0,31 – 0,50	Average High	Pasture
		0,51 – 0,80	High	Roads
		>0,80	Very high	Buildings

The Kb factor distribution (Fig. 3) shows high values for the residential areas and low values for forest cover.

The profile curvature takes into consideration the shape of the slope (linear, convex or concave). The negative values (Table 4) define convex slope with almost null landslide occurrence probability while the positive values define concave slopes with a high landslide occurrence probability (Fig. 4)

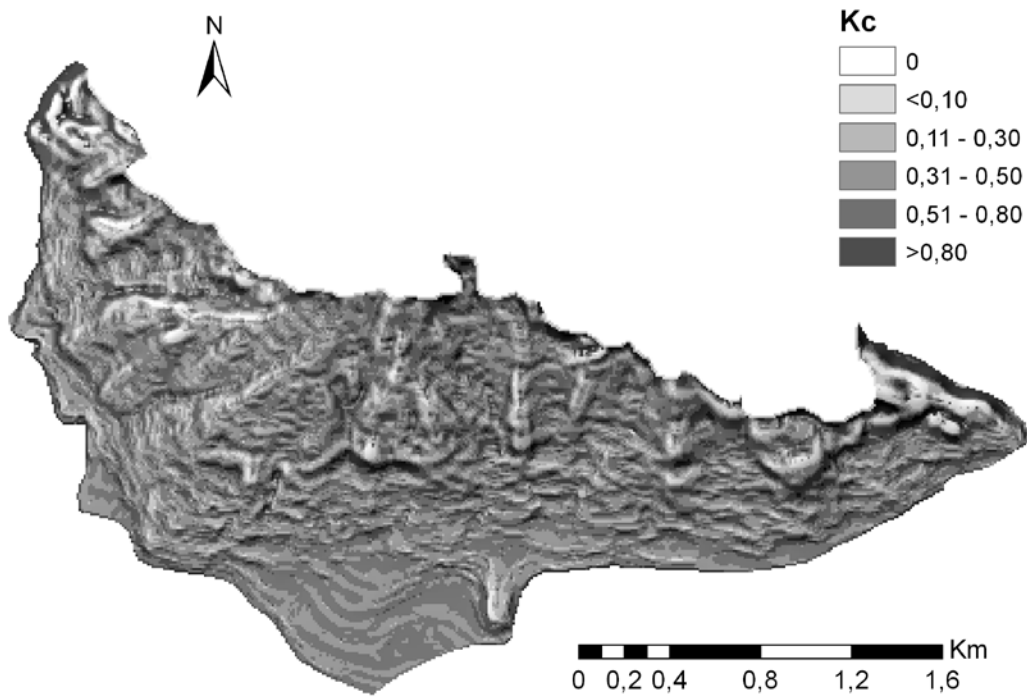


Figure 4. Distribution of the Kc factor (profile curvature)

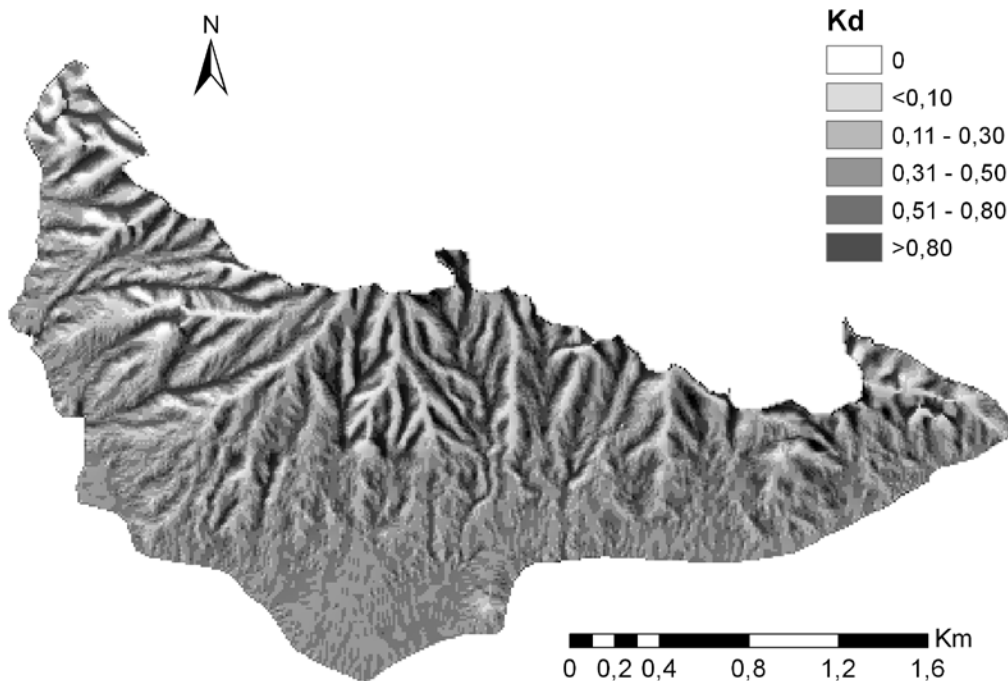


Figure 5. Distribution of the Kd factor (plan curvature)

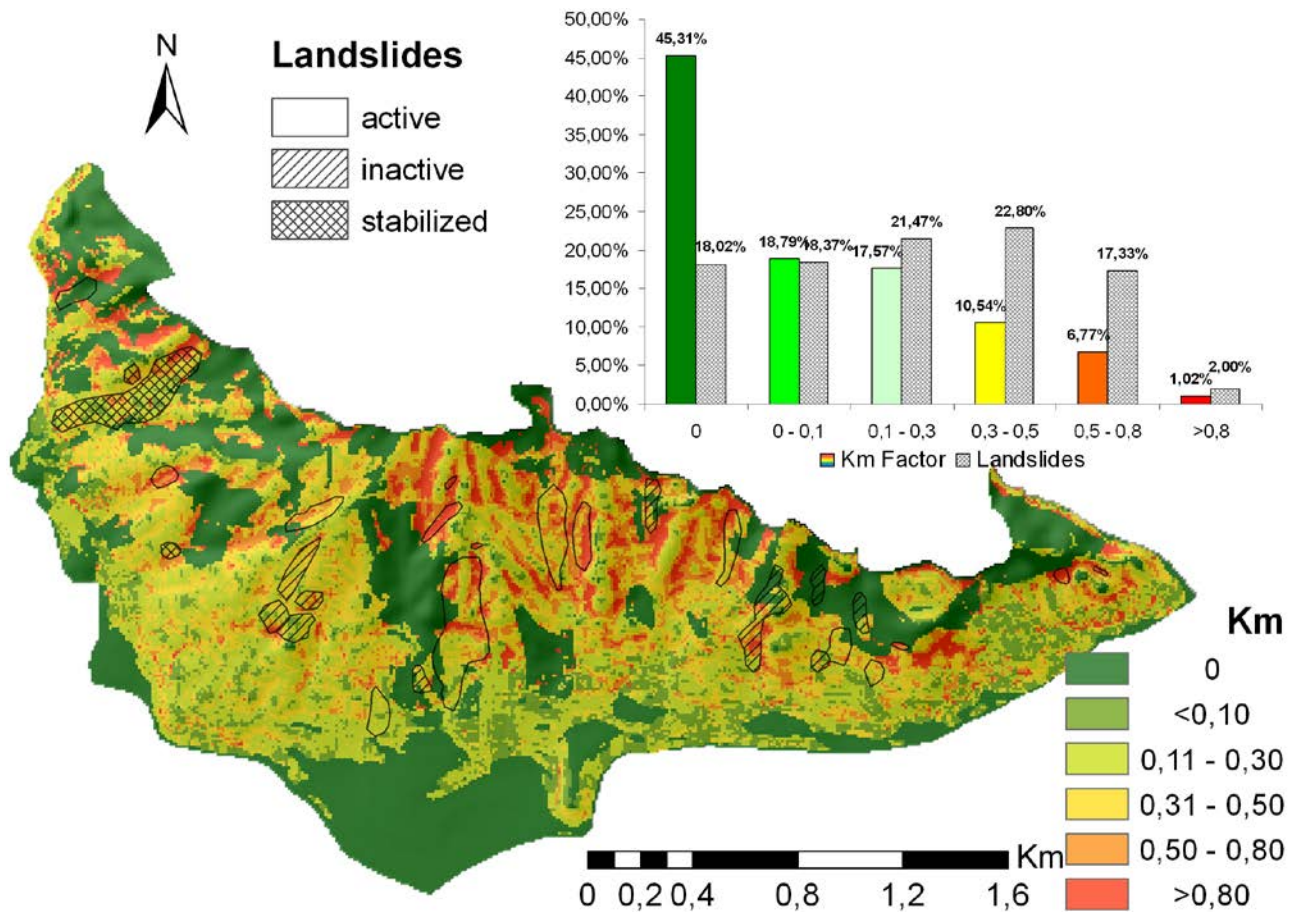


Figure 6. Distribution of the Km factor (landslide susceptibility map)

Table 4. Computed values for the profile curvature

Code	Parameter	Value	Probability	Intervals
Kc	Profile curvature	0	Almost null	<-0,5
		<0,10	Low	-0,5 – -0,2
		0,11 – 0,30	Average	-0,2 – 0
		0,31 – 0,50	Average High	0 – 0,2
		0,51 – 0,80	High	0,2 – 0,5
		>0,80	Very high	>0,5

Table 5. Computed values for the plan curvature

Code	Parameter	Value	Probability	Intervals
Kd	Plan curvature	0	Almost null	>0,5
		<0,10	Low	0,2 – 0,5
		0,11 – 0,30	Average	0 – 0,2
		0,31 – 0,50	Average High	-0,2 – 0
		0,51 – 0,80	High	-0,5 – -0,2
		>0,80	Very high	<-0,5

The plan curvature (Table 5) indicates high values for concave surfaces and low values for convex surfaces (Fig. 5)

The Km factor distribution (Fig. 6) shows high and very high susceptibility in the central areas of the glacis, and in the newly constructed

residential areas. The validation of the model was done by comparing the landslide map with the susceptibility map. Most of the active landslides fit the area characterized by average high (0.31 – 0.50) and high probabilities (0.50 – 0.80) representing more than 80% of the active landslides, while some of the old, stabilized landslide fit areas characterized by low and very low susceptibility. The most active landslides situated in the central part of the glacis are very recent, and most of them fit the very high susceptibility class. This region comprises of newly built residential areas that generated new landslides.

5. CONCLUSIONS

The proposed model show suitable results for areas prone to landslides in which newly built residential areas contribute to numerous landslide processes. 80% of the active landslides fitted the average-high and high susceptibility classes determined through modeling. Its suitability for this case study shows that the adaptation of well-known landslide assessment models to the local conditions can give better results than applying the actual models.

Acknowledgments

This work has been supported from the strategic grant POSDRU/159/1.5/S/133391, Project “*Doctoral and Post-doctoral programs of excellence for highly qualified human resources training for research in the field of Life sciences, Environment and Earth Science*” cofinanced by the European Social Fund within the Sectorial Operational Program Human Resources Development 2007 – 2013.

REFERENCES

- Arghiuș, Corina, Arghiuș, V.I., Ozunu, A., Muntean, L.O. & Mihăiescu, R.,** 2013. *Landslide susceptibility assessment in the Codrului Hills (north-western part of Romania)*. Carpathian Journal of Earth and Environmental Sciences, Vol. 8, No. 3, 137-144.
- Carrara, A., Guzzetti, F., Cardinali, M. & Reichenbach, P.,** 1998. *Current limitations in modeling landslide hazard*, In Buccianti, A., Nardi, G., and Potenza, R. (Eds.), Proceedings of IAMG 1998, 195-203
- Crozier, M.J. & Glade, T.,** 2005. *Landslide Hazard and Risk: Issues, Concepts and Approach*. Landslide Hazard and Risk, Edited by Th. Glade, M. Anderson, M J. Crozier, John Wiley & Sons, Ltd, 1-38.
- Fell, R., Corominas, J., Bonnard, C., Cascini, L., Leroi, E., Savage, W.Z.,** 2008. *Guidelines for landslide susceptibility, hazard and risk zoning for land use planning*. Engineering Geology, 102, 85-98.
- Guzzetti, F., Mondini, A.C., Cardinali, M., Fiorucci, F., Santangelo, M., Chang, K.-T.,** 2012. *Landslide inventory maps: new tools for an old problem*. Earth Sci. Rev., 112, 42-66.
- Măguț, Flavia-Luana, Zaharia, S., Irimuș, I. A.,** 2012. *Applied legislative methodology in the analysis of landslide hazard. Case study from Maramureș County*. Studia UBB Geographia, LVII, 2, 37-50.
- Montgomery, D.R., Dietrich, W.E.,** 1994. *A physically-based model for the topographic control on shallow landsliding*. Water Resources Research, 30, 1153-1171.
- Petrea, D., Bilașco, Ș., Roșca, Sanda, Vescan, I., Fodorean, I.,** 2014. *The determination of the landslide occurrence probability by GIS spatial analysis of the land morphometric characteristics (case study: the Transylvanian Plateau)*. Carpathian Journal of Earth and Environmental Sciences, Vol. 9, No. 2, 91-102.
- Pike, R.J., Sobieszczyk, S.,** 2008. *Soil slip/debris flow localized by site attributes and wind-driven rain in the San Francisco Bay region storm of January 1982*, Geomorphology 94 (3–4), 290-313.
- Shaw, S. C., Johnson D. H.,** 1995. *Slope morphology model derived from digital elevation data*. In: Proceedings, 1995, NW Arc/Info Users Conference. Coeur d'Alene, ID. October 23-25, 1995. 12 pp.
- Van Westen, C.J.,** 2004. *Geo-information tools for landslide risk assessment: an overview of recent developments*. Landslides, evaluation & stabilization: proceedings of the 9th international symposium on landslides, June 28 -July 2 2004, Rio de Janeiro, Brazil, Eds. Lacerda W, Ehrlich M, Fontoura S., Sayao A, 39-56.

Received at: 05. 06. 2014

Revised at: 15. 09. 2014

Accepted for publication at: 26. 09. 2014

Published online at: 03. 10. 2014