LANDSLIDE SUSCEPTIBILITY ASSESSMENT IN SOMESUL MARE HILLS USING HG MODEL AND GIS TECHNOLOGY

Colniță Dorel[*], Păcurar Ioan*, Roşca Sanda, Bilaşco Ştefan**, Negrușier Cornel*, Păcurar Horea***

*University of Agricultural Science and Veterinary Medicine Cluj-Napoca, 3-5 Manastur St., 5400372 Cluj-Napoca, Romania; e-mail: ioanpacurarcj@yahoo.com, cornelnegrusier@gmail.com, horea.pacurar@yahoo.com;
**"Babes-Bolyai" University, Faculty of Geography, 400006 Cluj-Napoca, Romania; sbilasco@geografie.ubbcluj.ro, sanda.rosca@geografie.ubbcluj.ro.
***Romanian Academy, Cluj-Napoca Subsidiary Geography Section, 400015, Cluj-Napoca, Romania.

Abstract

The aim of this study consists in framing the Hills of Someșul Mare, on a territory with high probability landslide classes according to the methodological recommendations of the HG 447/2003 using GIS technology and spatial analysis techniques. Statistical analysis of the data assigned to probability landslide classes was performed both for the entire analyzed territory and hydrographic sub-basins analyzing as natural units. The representativeness of the model for the analyzed area is given by the high value of the model validation coefficient R (80.2%) and outcome.

Keywords: landslide susceptibility, GIS modelling, Somesul Mare Hills, cumulated erosions

INTRODUCTION

In the category of negative processes that influence slope territories from the hilly areas in Romania, reducing its fertility (Guş et al., 1998), soil erosions (Costache, 1968; Moţoc, 1959; Ioniţă, 2000) and landslides (Petrea et al., 2014, Roşca, 2015a, Vâtcă et al., 2014; Moldovan et al., 2015). The aim of this study is to identify those areas framed in different probability classes of landslide appearance using GIS technologies and a complex database that includes favorable factors in Someșul Mare Hills. After mapping the lands, affected by landslides, 26 locations were identified for the total area of 1074 km^2 (Colniță et al., 2016).

MATERIAL AND METHOD

The identification of landslide probability involves the implementation of a spatial database which clearly shows the spatial variability of environmental factors that influence the occurrence and dynamics of these processes. The probability classes of landslides occurrence were obtained according to Romanian laws by HG 447/2003-*Methodological norms on the elaboration and content of natural risk maps on landslides*, providing the cumulation of preparatory and triggering factors of landslides considered major nationwide. They were included in a GIS database, technology that enables the spatialization of these triggers at both punctual and spatial level using interpolation techniques. GIS technology also allows the reclassification of each factor included in modelling on probability of landslides' occurrence classes using *Reclassify* functions that allow afterword to obtain probability coefficients for each class of the factors needed (Fig. 1).

Environmental hazard factor (km) that shows the potential or the probability of spatial landslides appearance was obtained using the formula proposed by HG 447/2003 using the Raster Calculator function from ArcMap 10.3 software.

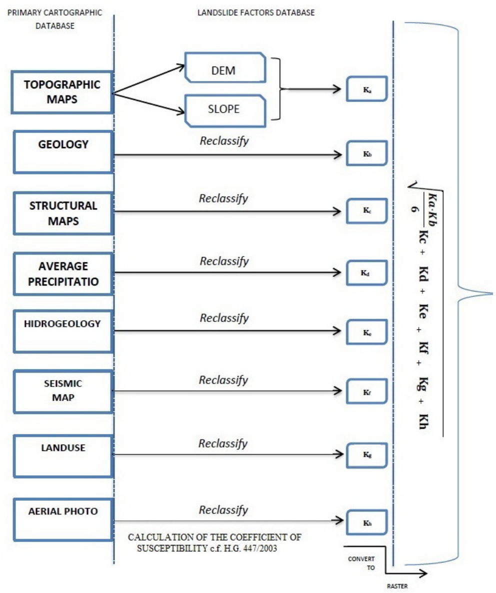


Fig. 1. Conceptual scheme for the determination of probability classes of landslide appearance according to HG methodology (Roșca et al., 2016) - *where: K(a)-lithologic factor, K(b)-geomorphologic factor, K(c)-structure factor, K(d)-hydro-climatic factor, K(e) -hydrogeologic factor, K(f)-seismic factor, K(g)-forest factor, K(h)-anthropic factor*

Lithologic factor K(a) highlights the influence of geology on the landslides appearance probability according to the national specificity. Database comprising geological features was obtained from the Geological Map of Romania, 1960. In terms of surface expanding, can be seen conglomerates, sandstones, marl clay (Hida Strate) on a territorial extension of 580 km^2; these receive a low hazard factor for landslides, according to the methodology, a value of only 0.25 that frames these territories in the class of medium probability. Sandstones and marl clay covering 206.5 km^2 frame these territories in high class probability of landslides appearance; the highest values for the unconsolidated sedimentary rocks and for the diapirism territories are 0.95 and 0.99, respectively (Table 1).

Table 1

The spatial extent of coefficient classes

	Ka	*Coefficient*	*Area (Km^2)*
Ka	0.01	Micaschists, paragneiss	1.77
	0.03	Andesite with pyroxene	0.29
	0.08	Rhiolites sm	0.09
	0.1	Dacite	2.06
	0.25	Conglomerates, sandstones, marl clay (Hida Strates)	580.55
	0.3	N. perforatus conglomerates, N. Fabiani limestones, marl, sandstone,marl-clay	3.08
		Marl, tuffs	40.40
	0.35	Facies marnos	109.45
	0.55	Sandstone, marl clay	206.59
	0.9	Clays, sandstones coal, marl, marl shale, tuffs	79.47
	0.95	Colluvial deposits	2.56
		Sands, gravel	34.92
		Gravel, sands	1.72
		Gravel, sands, debris	0.82
	0.99	Diapir of salt per day	0.51
Kb	0.1	Horizontally and slight slope specific to low hills	228.3
	0.3	Slight and moderate slope specific to middle hills	335.6
	0.5	High slope specific to high hills	275.0
	0.8	Very high slope specific to very high hills	164.5
	0.99	Steep specific to mountains	60.3
Kd	0.1	Areas with low rainfall, hydrographic basins located in hilly areas whose flow is controlled by rainfall	99.5
	0.15		50.0
	0.3		58.7
	0.35	Ares with moderate rainfall; the main valleys are the stage of maturity that the secondary effluents be to the stage of youth producing lateral and vertical erosions during floods and high flow.	137.3
	0.4		51.4
	0.5		97.4
	0.55	High levels of rainfall Valleys having predominantly vertical erosion.	325.0
	0.65		51.8
	0.7		99.4
	0.75		93.6
Ke	0.1	Sectors where ground water level does not affect stability of slopes.	327.60
	0.2		81.61
	0.35	Sectors where infiltrating forces influence the slopes stability	353.90
	0.5	Specific to slope sectors having springs at the base	300.84
Kg	0.1	Hydrographic sub-basins with an index of forestation > 70%	305.3
	0.5	Hydrographic sub-basins with an index of forestation 20-70%	448.0
	0.9	Hydrographic sub-basins with an index of forestation < 20%	311.0
Kh	0.1	Areas where no major works were executed on the slopes	111.2
	0.15	Areas where communication works were executed on different sectors of the slopes	378.1
	0.5		574.7

These territories are more limited in terms of spatiality, being found only on the Southwestern sector of the studied area (Fig. 3).

The geomorphological coefficient factor K(b) is extracted from Digital Elevation Model (DEM) and from the model of Someșul Mare Hillsides being classified on probability classes of landslides appearance (Fig. 4). The sector of middle hills has low and moderate slopes that occupies 335.6 km^2 with an average probability coefficient of 0.30.

The most susceptible areas to landslides are very high hills highly inclined sectors occupying 164.5 km^2 (Table 2) and the junction sector with nearby mountain branch characterized by very high slopes for 60,3 km^2.

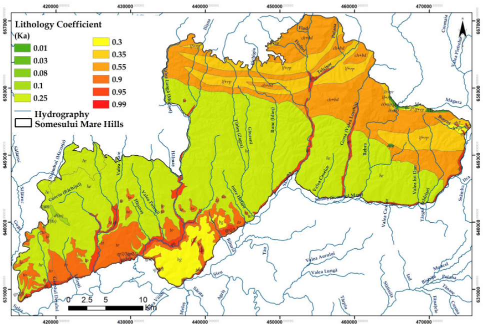


Fig. 3. Lithological coefficient map

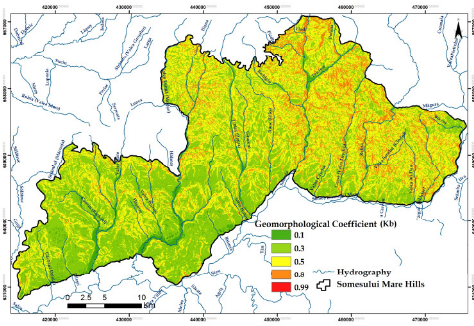


Fig. 4. Geomorphological coefficient map

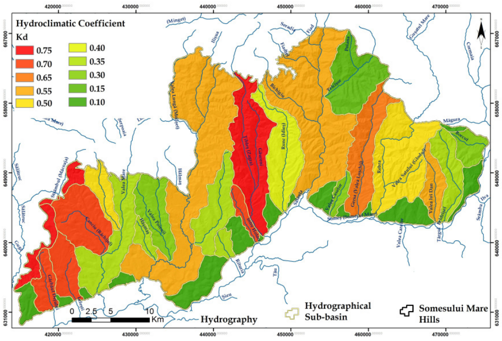


Fig. 5. Hydro-climatic coefficient map

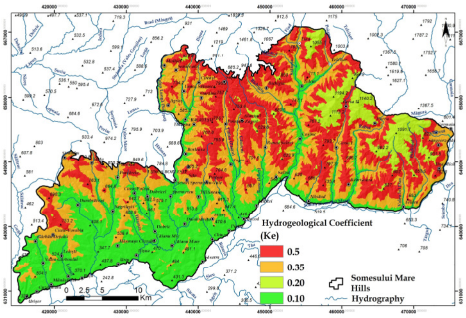


Fig. 6. Hydrogeological coefficient map

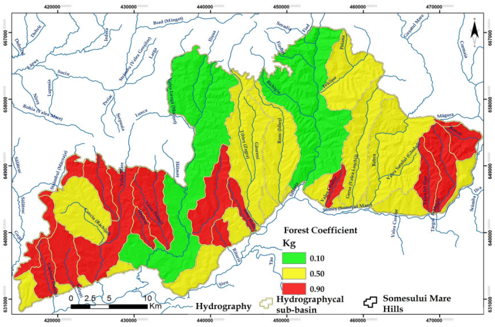


Fig. 7. Forest coefficient map

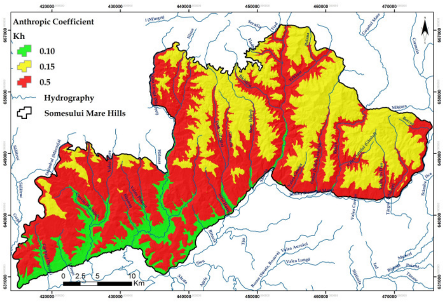


Fig. 8. Anthropical coefficient map

In order to obtain the map of the structural factor (Kc), given by the specific nature of Someșul Mare Hills, average values of 0.35 for the whole area were assigned, according to the methodology, which corresponds to a medium-high probability of landslides appearance.

Hydro-climatic coefficient K(d) has high impact on the appearance, dynamic or reactivation of landslides. The highest values were given to sub-basins that receive higher amount of rainfall and the lowest ones to the hilly areas whose flow is controlled by local rainfall.

Hydrogeological coefficient K(e) (Fig. 6) is in the range of 0.1-0.5 probability, noticing the distribution of territories characterized by low (0,1), medium (0,35) and medium-high (0,5) probability values on approximately equal surfaces around 300 km^2.

To the seismic coefficient of the studied area it was assigned value Kf=0.70 which corresponds to a very high probability of landslides appearance due to its location in the macro seismic zone 6 on MSK scale.

Forest coefficient K(g) was also assigned as hydroclimatic coefficient on the hydrographic sub-basins. Specific values of highest probability (0.90) corresponds to the hydrographic sub-basins with a forestation index less than 20%; those hydrographic sub-basins that have a forestation index over 70% (Valea Mare, Sălăuța, Fiad, etc) receive the lowest specific values due to high stability given by the forest coverage (Fig.7). Hydrographic sub-basins with a medium forest coverage (Țibleș, Rebra, Telcișor, etc) have the largest area of 448 km^2; they benefit of sectors with high slopes and a higher number of inferior affluent which cause instability processes.

The last coefficient recommended to be inserted in the model of determining probability range for landslides appearance is the anthropic coefficient (Kh) (Fig.8). This coefficient is related to the anthropic influence that often leads to slope instability by performing work on the transport network, causing changes in slopes for communication or housing infrastructure, even by deforesting to change land use.

RESULTS AND DISCUSSION

Applying the formula to identify the medium hazard coefficient on factors Ka and Kh, the value obtained for the probability of landslide appearance ranges from 0.02 to 0.726 (Fig. 9); so, on restricted sectors, there is a high degree of stability, the rest of natural and anthropic factors giving a dynamic character on different degrees to the territory. The result show that the classification resulted from the probability classes, due to minimum and maximum values recommended by HG 447/2003, highlight a medium probability class for an area of 733.86 km^2, being characterized by values between 0.1-0.3. The superior sector of Someșul Mare Hills, located within the administrative unit of Fiad, Telciu, Șerdaia, Parva, etc is framed on medium-high class of landslide appearance; class that characterizes 27% of the studied area (288.71 km^2).

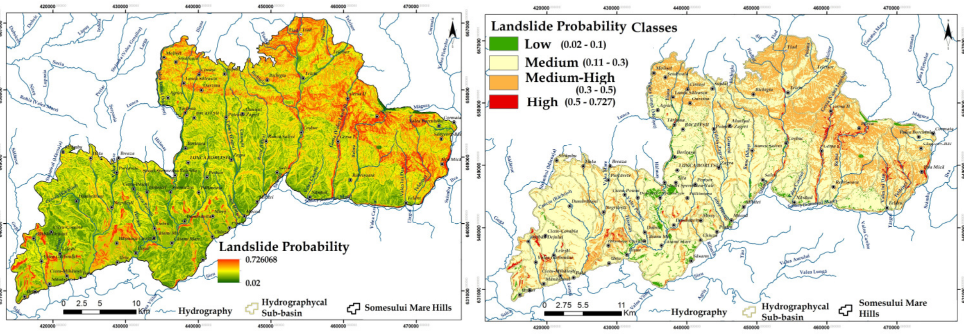


Fig. 9. The map of landslide probability appearance unclassified (left) and classified on probability classes (right)

Table 2

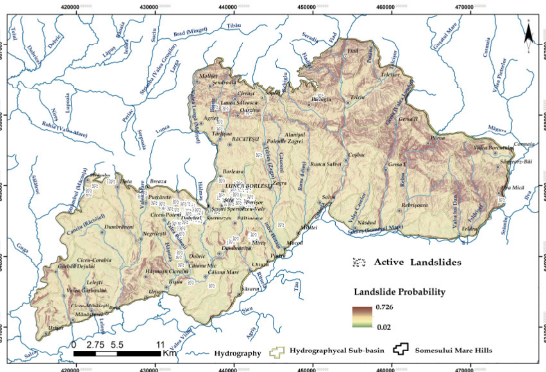
Spatial expansion of probability classes for landslide appearance at the hydrographic sub-basins level

No.	Hydrographic Sub-basin	Probability of landslide appearance			
		Minimum	Maximum	Average	Standard Deviation
1	Interbazinal	0.088	0.653	0.206	0.094
2	Fiad	0.089	0.632	0.287	0.099
3	Rebra	0.020	0.579	0.295	0.103
4	Telcişor	0.109	0.600	**0.303**	0.089
5	Ţibleş	0.099	0.547	0.225	0.079
6	Seradia	0.282	0.526	**0.471**	0.050
7	V. Lungă	0.089	0.645	0.230	0.092
8	Gersa	0.092	**0.708**	0.300	0.115
9	Runc	0.095	0.581	0.219	0.074
10	Măgura	0.020	0.495	0.234	0.163
11	Valea Mare	0.101	**0.684**	0.237	0.100
12	Borcut	0.119	0.513	0.271	0.089
13	Feldrişel	0.035	0.547	**0.322**	0.098
14	Sălătruc	0.071	**0.726**	0.240	0.118
15	V. lui Dan	0.097	0.564	**0.303**	0.099
16	V. Negrileştilor	0.105	0.691	0.229	0.071
17	Strâmbul	0.110	0.391	0.235	0.068
18	Dumbrăviţa	0.089	0.684	0.207	0.092
19	Dobricel	0.089	0.624	0.209	0.073
20	V. Caselor	0.092	0.368	0.216	0.063
21	Canciu	0.070	0.557	0.190	0.060
22	Între Hotare	0.097	**0.714**	0.218	0.081
23	Hăşmaş	0.089	**0.684**	0.234	0.094
24	Rituria	0.106	0.615	0.223	0.084
25	Leleşti	0.071	**0.721**	0.211	0.101
26	Gârbăul Dejului	0.088	**0.721**	0.258	0.115

On small areas of 12,2 km^2, located in the hilly sectors of Gârboul Dejului, Uriu, Hăşmaşul Ciceului, Dumbrăviţa, Valea Luşchi, Sălăuţa, Feldrişel and Ilva, the probability of landslides is very high, ranging from 0.5 to 0.7.

Analyzing the values of the probability of landslide appearance in basins, it medium-high values can be noticed in the sub-basins of: Telcişor (0,303), Şeradia (0.471), Feldrişel (0.322) and Valea lui Dan, with an average probability of 0.303, which ranks these territories into a medium-high class of landslide appearance (Table 2).

To validate the applied model and to identify the representativeness in the specialized studies, a wide range of methods were used such as predicting success rate (Chung and Fabbri, 2008), estimating the prediction rate, identification of ROC curve (Relative Operating Characteristic) and AUROC (Area Under the Receiver Operating Characteristic Curve) and R index (Roşca, 2015b).



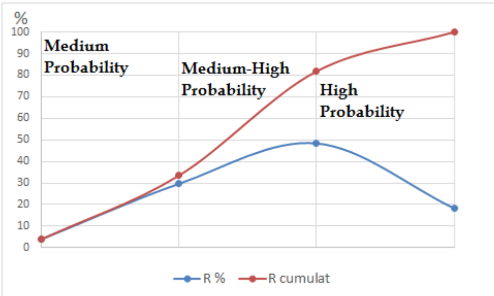


Fig. 10. Spatiality and R index value validation for model determination of the probability of landslide appearance

CONCLUSIONS

In the present study, there was identified the probability of landslide appearance according to HG 447/2003 which allowed the framing on probability classes for the whole analyzed territory and also at the sub-basin level. In order to validate these values, the R coefficient values were identified that indicate the percentage of the area affected by active landslides that overlap the classes characterized by different probability values. A good correlation of the spatial position of active landslides on classes can be seen with probability values higher than 0.3 (Fig. 9). R percentage index indicating a high degree of the results; validation given by the fact that 80.2% of active landslides are found in the probability class modelled by medium and medium-high landslides appearance. It emerges representativeness of the chosen model for the study area and measures can be proposed in order to overcome the negative effects induced by landslides through limiting the overloading of slopes with buildings, and diminishing deforestation and implementing measures to strengthen the slopes.

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