SPATIAL ANALYSIS OF LANDSLIDES USING GIS. CASE STUDY: HÂRTIBACIU PLATEAU

G.ROŞIAN[1], CS,HORVATH [2], G.DOBREI [1] ROZALIA BENEDEK[2]

Abstract: **- Spatial analysis of landslides using GIS. Case study: Hârtibaciu Plateau.** From all the geomorphological processes, specific to Hârtibaciu Plateau, landslides stand out. The Hârtibaciu Plateau is placed geographically on the south-eastern part of the Transylvanian Basin (a large depression area placed in the interior of Carpathian Mountains). In order to analyse the distribution of the landslides we took into consideration 5 criteria: geology, altitude, slope, exposition and the administrative units. This type of study is necessary on one hand to find out the way in which the current landslides are distributed, on the other hand, the research will collect information on the susceptible areas which are prone to this type of geomorphological processes. Following the analysis of the ortophotoplans and topographic maps a number of 1771 landslides were vectorised. Considering the land use, landslides are found mainly on agricultural lands. Taking into consideration the lithologic conditions (the presence of friable rocks such as clays, marls, clay marls) and the land use (mostly agricultural lands), it is believed that in the future landslides will appear on similar slope, orientation and geological conditions etc. In this situation, knowing the susceptible areas to landslides is beneficial also for the territorial planning actions but also to avoid the settlement of buildings and other civil engineering constructions on lands which are prone to landslides.

Keywords: landslides, spatial statistics, distribution, GIS.

1. INTRODUCERE

One of the main geomorphological processes from Hârtibaciu Plateau is represented by landslides. The Hârtibaciu Plateau is placed in the south-eastern part of the Transylvanian Basin (Fig. 1); from the proximal units, it is delimitated by valley corridors and depressions. In this regard we distinguish, the Târnava Mare Corridor in the North, Visei Corridor and Sibiu Depression in the West, Făgăraş

[1] Babeş–Bolyai University, Faculty of Environmental Science and Engineering, 400294, Fântânele Street, No. 30, Cluj–Napoca, Romania; e-mail: georgerosian@yahoo.com; gabriel.dobrei@gmail.com
[2] Babeş-Bolyai University, Faculty of Geography, 400006, Clinicilor Street, No. 5-7, Cluj-Napoca, Romania; e-mail: hcsaba@gmail.com
[2] Babeş-Bolyai University, Faculty of Geography, Zalau Branch, Romania; e-mail: rozaliabenedek@yahoo.com

Depression in the South and Archita and Paloş Valley in the East. On its 361795 ha surface 1771 landslides were identified, which represent 17272 ha.

These are, on one side the result of the geological substrates, and on the other side the result of the land use which is significantly influenced by the anthropic. Under lithological aspect it is especially noticeable the presence of friable rocks like clays, clay marls etc., as a result of sedimentation of eroded materials from the Carpathian Mountains, which delimitate the Transylvanian Basin (Sanders et al., 2002; Krezsek & Filipescu 2005; Krezsek and Bally, 2006). We must mention that even if it is a depressionary space, it has the aspect of a hilly landform, which is the result of fluvial modelling of the mentioned lithological formations. The anthropic had also a significant role in triggering the geomorphological processes, one must only think to land use.

The forest's place, which had also a slope retaining role, was initially taken by the grasslands (they were used as a meadows), and afterwards, as mechanization took over agriculture, these were transformed mostly in arable lands. Given these land use changes and considering also the friable lithology, landslides type geomorphological processes did not take long to occur (Roşian et al., 2010).

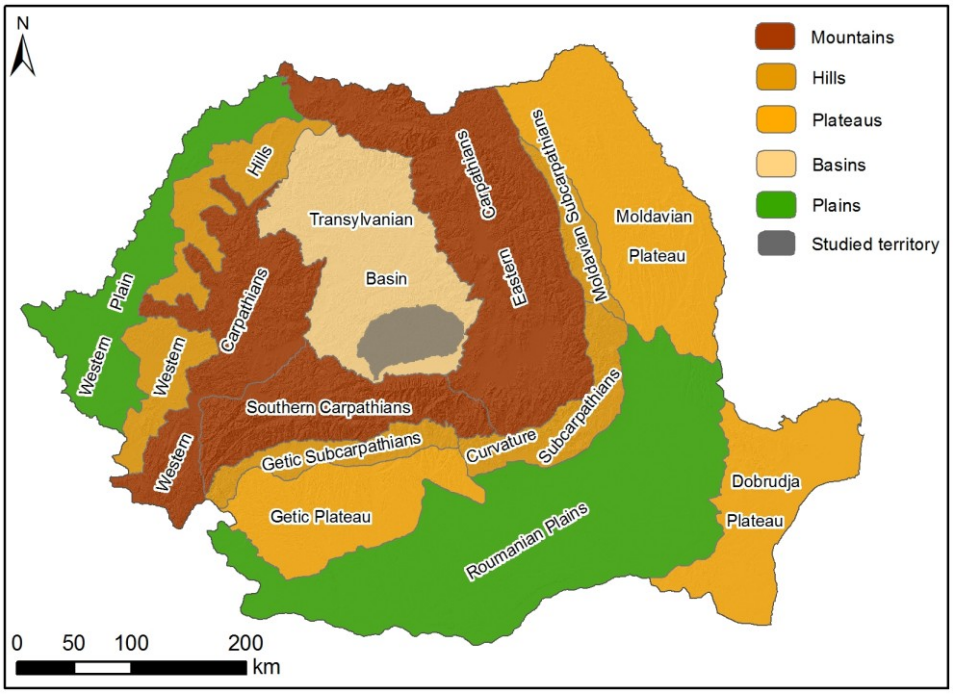

Figure. 1. Localization of the study area

Thus, the Hârtibaciu Plateau landslides distribution statistical analysis proves to be extremely useful, given the fact that the causes and triggering factors of these geomorphological processes are still the same nowadays. Therefore, we present the current distribution of landslide as well as data about possible areas that in the future might be affected by such processes.

2. METHODS AND RESOURCES

A GIS spatial analysis methodology was used in order to identify the landslide distribution within Hârtibaciu Plateau based on five criteria (geology, altitude, slope, slope orientation and administrative units), taking also into consideration field observations.

Landslide identification was made using 1:5000 orthophotos, based on which, using a GIS software (ArcMap 10.22), landslides were vectorized using its Editor function. Also, field observations were made and where landslide delimitation was not possible by using ortophotoplans, the GPS (Global Positioning System) method was applied; the information from field observations were then downloaded and introduced into a GIS in order for them to be processed.

Subsequently, based on the classes of each criterion, (geological age, altitude intervals, slope values, orientation type etc.) the landslides were analyzed to identify their distribution and extension. For this purpose, we identified the areas exposed to landslides by using Esri's ArcGIS toolbox Spatial Analyst tools/Zonal/Tabulate Area tool which computes the areas for each class defined by the analysis, it uses the classes as defined zones and computes the area which is affected by the studied phenomena. We also analysed the number of slides in each class, this was accomplished by identifying the gravitational point of every vectorised landslide polygon, and this point was used to compute density.

3. RESULTS AND DISCUSSIONS

After vectorizations of landslides from orthophotos, the statistics say that in the Hârtibaciu Plateau, there are 1771 landslides which represent 17272 ha. Given that the geographic unit surface is of 361795 ha, it results that 4.77% of its surface is affected by landslides.

From a landslide distribution perspective, starting from the five criteria taken into consideration, we reached the following results.

From a geological point of view (CONFORTI et al 2012) Badenian (marls), Sarmatian (clay marls) and Pannonian deposits (clays, sands) prevail along with the Quaternary deposits (Pleistocene and Holocene). As it results from Figure 2 and Table 1, landslides mostly affect the areas belonging to the Sarmatian era.

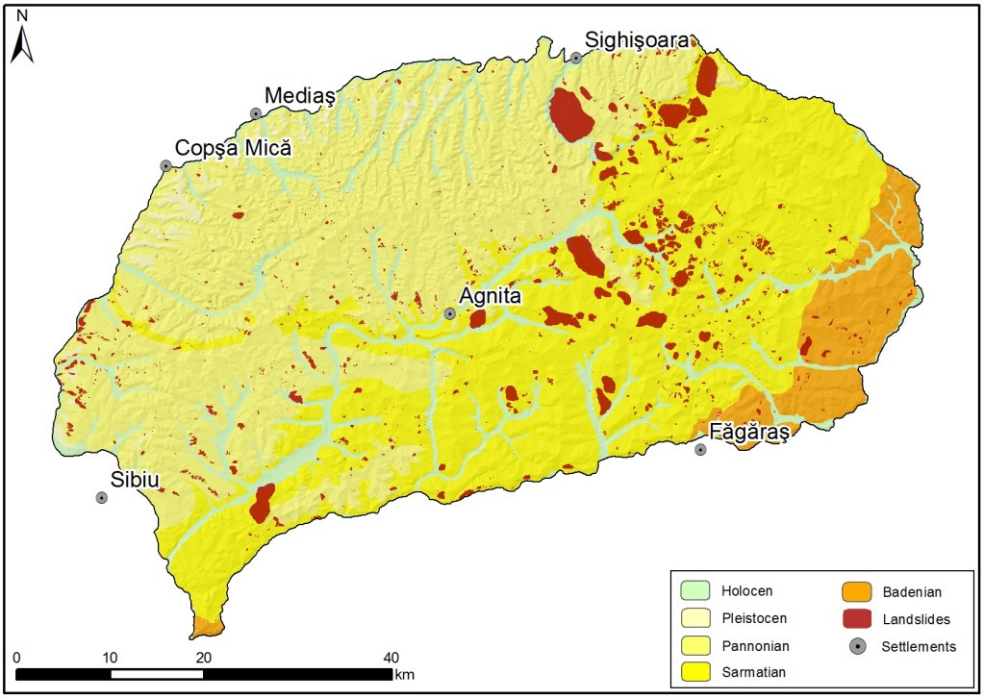

Fig. 2. Geological map

Table 1. Landslide distribution based on geological deposits

Geological deposits	Landslide number	Landslide surface (ha)	Percentage (%)
Holocen	69	698	4
Pleistocen	8	19	1
Pannonian	862	5344	31
Sarmatian	765	10650	61
Badenian	67	561	3
Total	1771	17272	100

In order to observe landslide distribution from an altitude perspective (Roşian et al. 2016), five altitude classes were chosen: 284 - 400 m, 400 – 500 m, 500 – 600 m, 600 – 700 m and şi 700 – 808 m (Figure 3). As it results from Table 2, the majority of landslides belong to the altitude range 500 – 600 m and the largest surface is also specific to the 500 – 600 m range.

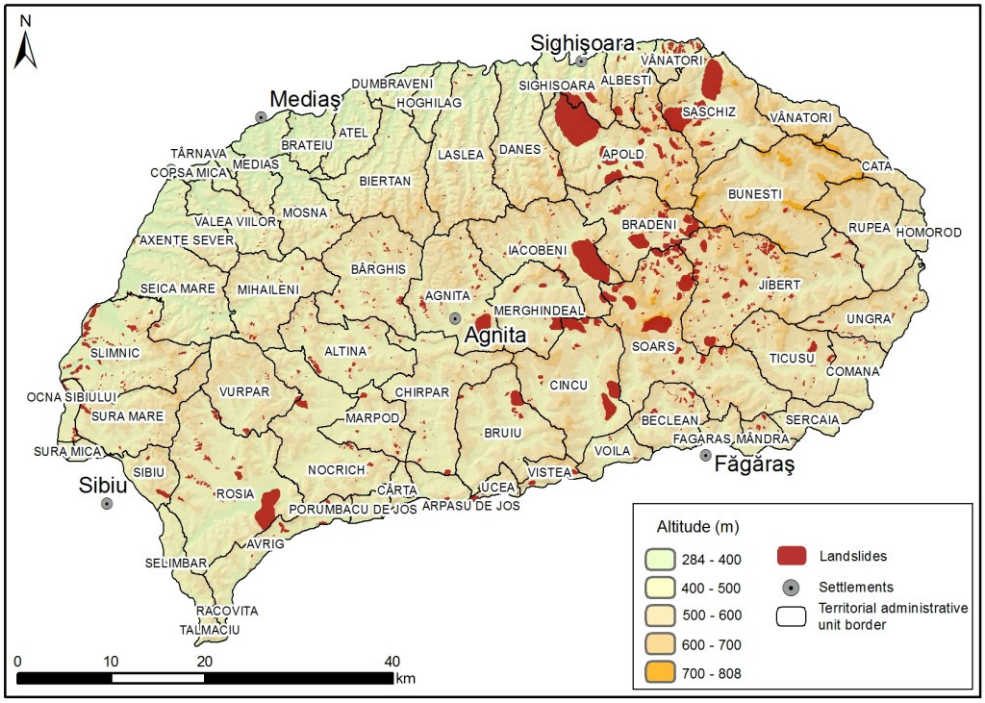

Fig. 3. The map of altitude range

Table 2. Landslide distribution based on altitude range

Altitude range (m)	Landslide number	Landslide surface (ha)	Percentage (%)
284 - 400	92	580	3
400 - 500	662	6295	37
500 – 600	883	8644	50
600 – 700	134	1753	10
700 – 808	0	0	0
Total	1771	17272	100

Another indicator of landslide distribution is represented by slope (Bourenane et al 2015). Starting from the previous field classifications depending on slope, for the Hârtibaciu Plateau seven classes were chosen: $0 – 2^o$, $2 – 5^o$, $5 – 7^o$, $7 – 12^o$, $12 – 17^o$, $17 – 22^o$ şi $22 – 42^o$ (Figure 4). As it can be noticed on Table 3, the majority of landslides belong to the $7^o – 12^o$ slope category and the largest surface is specific to the same range.

Tabelul 3. Landslide distribution based on slope categories

Slope category (°)	Landslide number	Landslide surface (ha)	Percentage (%)
0 - 2	14	860	5
2 - 5	128	5053	29
5 - 7	273	3620	21
7 – 12	794	5967	34
12 - 17	415	1375	8
17 - 22	124	299	2
22 – 42	23	98	1
Total	1771	17272	100

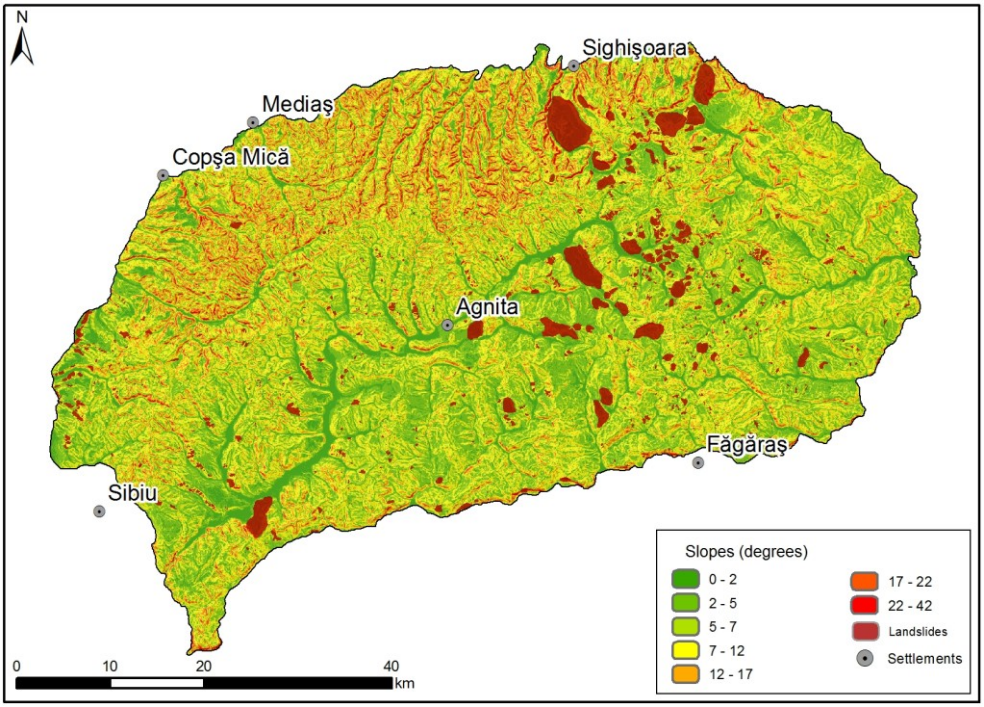

Fig. 4. Slope map

An important criterion taken into consideration to observe landslide distribution is represented by slope orientation (Fig. 5) (Yalcin et al 2011, Bilasco et al 2011). The exposure to the sun energy decisively determines the heat condition, soil and humidity, it influences the freezing-melting processes, the type and nature of the superficial deposits on the slopes and leads to qualitative differences in the ongoing processes preceding erosion (Jakab, 1979). In Table 4,

we notice that the surfaces that have a South-western orientation are mostly affected by landslides. Also, from a surface perspective, the highest values are specific to South-western slopes.

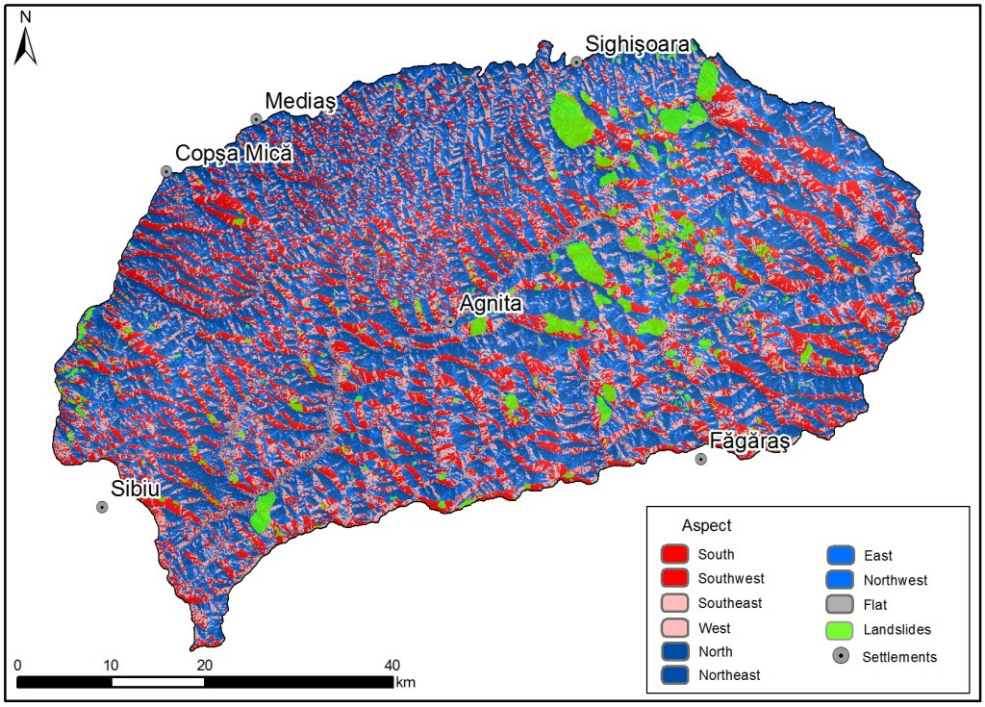

Fig. 5. Landform exposure map

Tabelul 4. Landslide distribution based on exposure

Exposure towards to the sun	Exposure towards Compass directions	Landslide number	Landslide surfaces (ha)	Percentage (%)
Sunny	South	310	2581	15
	South-West	412	4026	23
Partial sunny	South-East	122	1351	8
	West	302	3420	20
Shady	North	159	1519	9
	North-East	122	1125	6
Partial shady	East	114	909	5
	North-West	230	2341	14
Flat		0	0	0
Total		1771	17272	100

In regards to landslide distribution we took in consideration also the administrative units, for the Hârtibaciu Plateau. We considered this subdivision because al territorial planning and future interventions, with national or international budgets, are limited by the administrative hierarchy and so it represent a must in the present situation landslide and erosion analysis and statistics. So, the following situation unfolded: there are 61 administrative units of which 57 are affected by landslides. The situation of the ten most affected administrative divisions from the landslide extent and number is shown in the table 5 and 6.

Table 5. Landslide distribution at the administrative units level by affected areas

Name	Studied territory surface (ha)	Landslide surface (ha)	Percentage of the affected surface (%)	Number of landslide
Apold	12536	2648	21	47
Saschiz	9785	1853	19	45
Şoarş	17247	1767	10	124
Iacobeni	10326	1256	11	48
Brădeni	8156	1150	14	60
Jibert	16481	1107	7	188
Roşia	16249	1015	6	59
Cincu	11841	961	8	27
Slimnic	10320	589	6	103
Agnita	9778	474	5	51

Tabelul 6. Administrative units landslide distribution by landslide number

Name	Studied territory surface (ha)	Landslide surface (ha)	Percentage of the affected surface (%)	Number of landslide
Jibert	16481	188	1107	7
Şoarş	17247	124	1767	10
Bîrghiş	9986	114	206	2
Slimnic	10320	103	589	6
Laslea	10889	76	54	1
Alţâna	8047	75	224	3
Brădeni	8156	60	1150	14
Roşia	16249	59	1015	6
Şeica Mare	9370	59	80	1
Agnita	9778	51	474	5

4. CONCLUSIONS

In regards to landslide type, in most of the cases, these are of a superficial and of medium depth (Varnes, 1978). Their large number is tightly bound, along with the land use, also to the geological characteristics. They are Miocene age formations that belong to Badenian, Sarmatian Sarmatian. For Badenian marls are typical, for Badenian clay marls, and for Pannonian clays and sands. These clays have in their composition montmorillonite, illite and beidellite mineral which can retain water. Taking into consideration that it is a hilly area made of the mentioned lithology, there is a highly susceptibility to landslides.

Hence, from a spatial distribution analysis perspective, the conclusions that can be drawn are that the most affected by landslides are the area overlapped with Sarmatian deposits, those on an altitude range of 500 - 600 m and those which have an angle of inclination of 7 – 12 degrees, but also those with a South-western orientation. At the administrative units level the most affected are: Apold, Saschiz, Şoarş, Iacobeni, Brădeni, Jibert, Roşia, Cincu, Slimnic, Agnita, Bârghiş, Laslea, Altâna, Şeica Mare etc. This can be explained by the fact that within these communes territory Sarmatian deposits prevail, altitudes range mainly between 500 - 600 m, slopes have an angle of inclination of 7 – 12 degrees and the prevailing orientation of slopes is South-western.

When all these come together we need to take actions against landslides within the area of the Hârtibaciu Plateau. Considering also the susceptibility of area to other type of landslides, along with the combative measures, preventive measures are also necessary. It is recommended in this regard the change of the used agricultural technique, the prevention of water oversaturation of slopes by quick drainage of precipitation, streams or groundwater.

Given the number of landslides and the areas affected by them in the Transylvanian Depression it is necessary to extend the research method to all the other regional subunits of Transylvania (Târnava Mică Hills, Secaşelor Plateau, Somşan Plateau, Transylvanian Plain etc.).

REFERENCES

1. BILASCO S, HORVATH C, ROSIAN G, FILIP S, KELLER E (2011). *Statistical model using GIS for the assessment of landslide susceptibility. Case study: the Somes plateau.* Rom J Geogra-phy 55(2):91-101.
2. BOURENANE H, BOUHADAD Y, GUETTOUCHE MS, BRAHAM M (2015) GIS-based landslide susceptibility zonation using bivariate statistical and expert approaches in the city of Constantine (Northeast Algeria), Bulletin of Engineering Geology and the Environment 2015, Volume 74, Issue 2, pp 337-355. doi: 10.1007/s10064-014-0616-6
3. CONFORTI M, ROBUSTELLI G, MUTO F, CRITELLI S (2012) *Application and validation of bivariate GIS-based landslide susceptibility assessment for the Vitravo river catchment (Calabria, south Italy)* Nat. Hazard, 61 (2012), pp. 127–141. doi:10.1007/s11069-011-9781-0
4. JAKAB, S. (1979), *Asimetria versanţilor din Dealurile Târnavei Mici şi ale Nirajului*, Trav. Station „Stejarul", Seria Geologie-Geografie, Nr. 7, pp. 23-33
5. KRÉZSEK, C., BALLY, W.A. (2006), *The Transylvanian Basin (Romania) and its relation to the Carpathian fold and thrustbelt: Insights in the gravitational salt tectonics*, Marine and Petroleum Geology, vol. 23 (4), pp. 405-442.
6. KRÉZSEK, C., FILIPESCU, S. (2005), *Middleto late Miocene sequence stratigraphy of the Transylvanian Basin (Romania)*, Tectonophysics, vol. 410 (1-4), pp. 437-463.
7. ROŞIAN, G., RUSU, R., TAHÂŞ, S. (2010), *The Degree of Finishing of the Drainage Basins of the Transylvanian Depression*, S*tudia Universitatis Babeş-Bolyai, Cluj-Napoca, Seria Geographia*, vol. 58, pp. 69-76.
8. Roşian, G, Horváth Cs; Réti Kinga-Olga,; Boţan, C. N.; Gavrilă, Ionela Georgiana (2016) *Assessing landslide vulnerability using bivariate statistical analysis and the frequency ratio model. Case study: Transylvanian Plain (Romania)*, Zeitschrift für Geomorphologie, NF Volume 60 Issue 4 (2016), p. 359 – 371, DOI: 10.1127/zfg/2016/0404
9. SANDERS, C., HUISMANS, R., VANWEES, J.D., ANDRIESSEN, P. (2002), *The Neogene history of the Transylvanian basin in relation to its surrounding mountains*, European Geosciences Union, Stephan Mueller Special Publication Series, vol. 3, pp. 121-133.
10. VARNES, D.J., (1978), *Slope movement types and processes*, In Landslides, Analysis and Control, Special Report 176, Transportation Research Board, Washington, p. 11-33.
11. YALCIN A, REIS S, AYDINOGLU A C, YOMRALIOGLU T (2011). *A GIS-based comparative study of frequency ratio, analytical hierarchy process, bivariate statistics and logistics regression methods for landslide susceptibility mapping in Trabzon, NE Turkey*. Catena, 85(3), 274–287. doi:10.1016/j.catena.2011.01.014.