LANDSLIDE SPATIAL DISTRIBUTION ANALYSIS USING GIS. CASE STUDY SECAŞELOR PLATEAU

GH.ROŞIAN [1], CS.HORVATH[2], A.NIȚĂ [3], ROZALIA BENEDEK[4]

Abstract: - **Landslide Spatial Distribution Analysis Using GIS. Case Study Secaşelor Plateau**. Landslides represent an extremely frequent geomorphological phenomenon in the Secaşelor Plateau. The regional unit is located in the South-Eastern part of the Transylvanian Basin (large basin within the Carpathian Mountains). In this paper, we analyzed the distribution of the landslides through spatial statistics techniques and GIS. In order to analyze the distribution of the landslides we took into consideration 5 criteria: geology, height, slope, exposition and the territorial administrative units. This type of study is necessary to find out the way in which the actual landslides are distributed and on the other hand, the research will collect information on the susceptible fields which are favored by these geomorphological processes. After the visual analysis of the area using the 1:5000 aerial photography and topographic maps, 835 landslides were identified and vectorized. At the level of administrative-territorial units, these cover mostly agricultural areas. Given the lithological conditions (the presence of friable rocks of marl, clay and poorly cemented sands) and the land use (mostly agricultural) it can be said that in the future new landslides will ocure in similar conditions of slope, exposition and geological characteristic etc. The identification of areas that are susceptible to landslides is beneficial for the future territorial planning actions and also to avoid building on areas which are prone to landslides.

Key-words: landslides, spatial statistics, distribution, GIS.

1. INTRODUCTION

Secaşelor Plateau is located in the South-Eastern part of Transylvanian Basin (Fig. 1), its main geomorphological processes are given by landslides. The borders of the Secaşelor Plateau are formed by wide river valleys and depressions. One must

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

note, in this regard, the Târnava Mare and Târnava valleys in the North, Mureș in the West, Visa in the East and in the South the Sibiu and Apold depressions. Within the 10855 ha Secașelor Plateau we identified 835 landslides.

They are, on one side, the consequence of the lithologic conditions and on the other side, the direct consequence of the land use. From a lithological perspective, one notices the presence of the friable rocks like marl, clay and poorly cemented sands etc., which are the result of sedimentation from the eroded materials of the Carpathian Mountains that delineate the Transylvanian Basin. (Sanders et al., 2002; Krezsek and Filipescu 2005; Krezsek and Bally, 2006). Also, we must highlight the fact that the anthropic factors played a decisive role in triggering the geomorphological processed, especially from the land use perspective. This, in the conditions in which previously the anthropic intervention, over 90% of the land areas were covered by forest, nowadays, the value is constantly under at 10% (Pop, 2001).

The forests place, which had also a slope stabilizing role, was initially taken by 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).

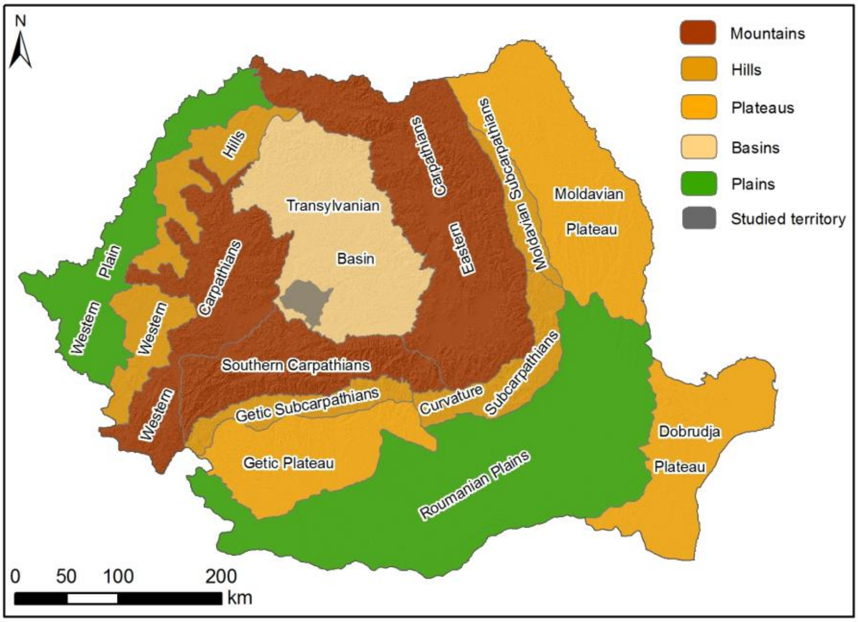

Figure. 1. Localization of the study area

Thus, the Transylvanian Plain's 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. So, 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

To find the Secaşelor Plateau landslides distribution, we considered five spatial analysis criteria (geology, altitude, slope, exposition and administrative units), alongside field observations we also used a GIS methodology.

Landslide identification was made using 1:5000 orthophotos, based on which, using a GIS software (ArcMap 10.2), landslides were vectorised 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 software to be processed.

Subsequently, based on the classes of each criterion, (geological age, altitude intervals, slope values, exposure type etc.) the landslides were analysed 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 DISCUSSION

From the vectorization of landslides, from aerial photography and topographic maps in the that Secașelor Plateau, we count an amount of 835 (10855 ha). Given that the surface of the specified regional division is of 120899 ha, it results that 8.97% of the surface is affected by landslides.

From the landslide distribution perspective, based on the five criteria taken into consideration we reached the following results.

Geologically speaking, Badenian (marl clay, sand, tufa) Sarmatian deposits (marl, sand) and Pannonian deposits (clay, sand) prevail along with the Quaternary deposits (Pleistocene and Holocene). As it results from Figure 2 and Table 1, landslides mostly take place on the Pannonian surfaces.

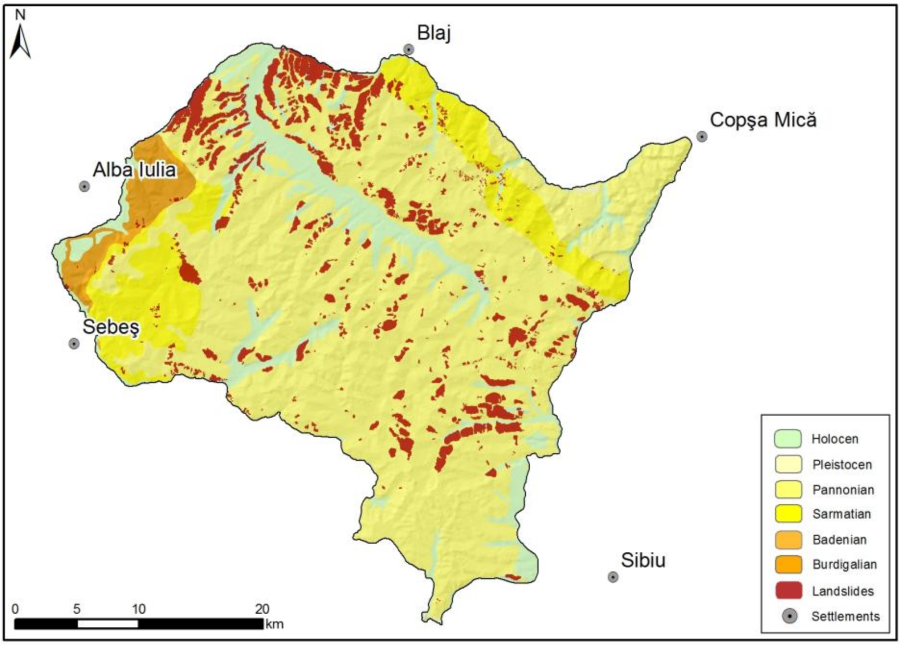

Figure 2. Geological map

Table 1. Landslide distribution based on geological deposits

Geological deposits	Landslide number	Landslide surface (ha)	Percentage (%)
Holocen	9	820	7
Pleistocen	43	253	2
Pannonian	615	9135	84
Sarmaţian	144	593	5
Badenian	7	15	1
Burdigalian	17	39	1
Total	835	10855	

In order to observe landslide distribution from an altitude perspective, five altitude ranges were chosen: 216 - 300 m, 300 – 400 m, 400 – 500 m, 500 – 600 m şi 600 – 638 m (Fig.3). As one can see from Table 2, most of landslides belong to the altitude range 300 – 400 m and the largest surface is specific also to this 300 – 400 m range.

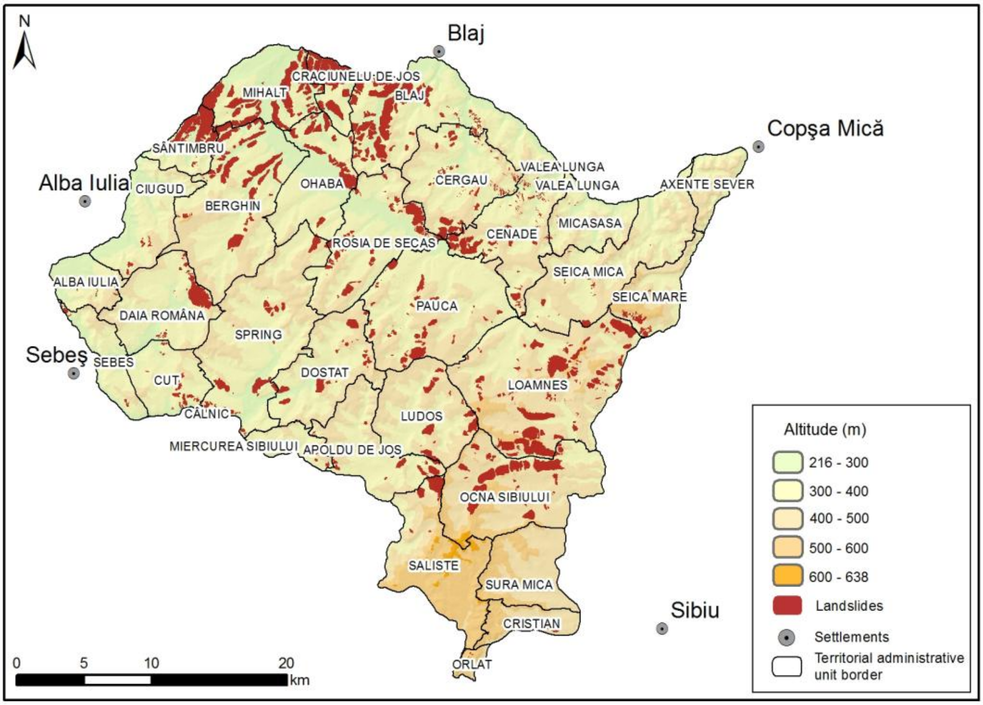

Fig. 3. The map of altitude range

Table 2. Landslide distribution based on altitude range

Altitude range (m)	**Landslide number**	**Landslide surface (ha)**	**Percentage (%)**
216 - 300	83	2209	20
300 - 400	482	5432	50
400 – 500	257	3030	28
500 – 600	13	184	2
600 – 638	0	0	0
Total	835	10855	100

Another indicator of landslide distribution is the slope. Starting from the previous field classifications based on slope, for Secașelor Plateau seven categories were chosen: $0 – 2^o$, $2 – 5^o$, $5 – 7^o$, $7 – 12^o$, $12 – 17^o$, $17 – 22^o$ şi $22 – 39^o$ (Fig.4). As it can be noticed (Table 3), most landslides belong to the $7 – 12^o$ slope category and the largest surface is specific to the same range.

Table 3. Landslide distribution based on slope categories

Slope category (°)	Landslide number	Landslide surface (ha)	Percentage (%)
0 - 2	1	50	1
2 - 5	39	1255	11
5 - 7	135	2847	26
7 – 12	452	5729	53
12 - 17	173	833	7
17 - 22	31	52	1
22 – 39	4	89	1
Total	835	10855	100

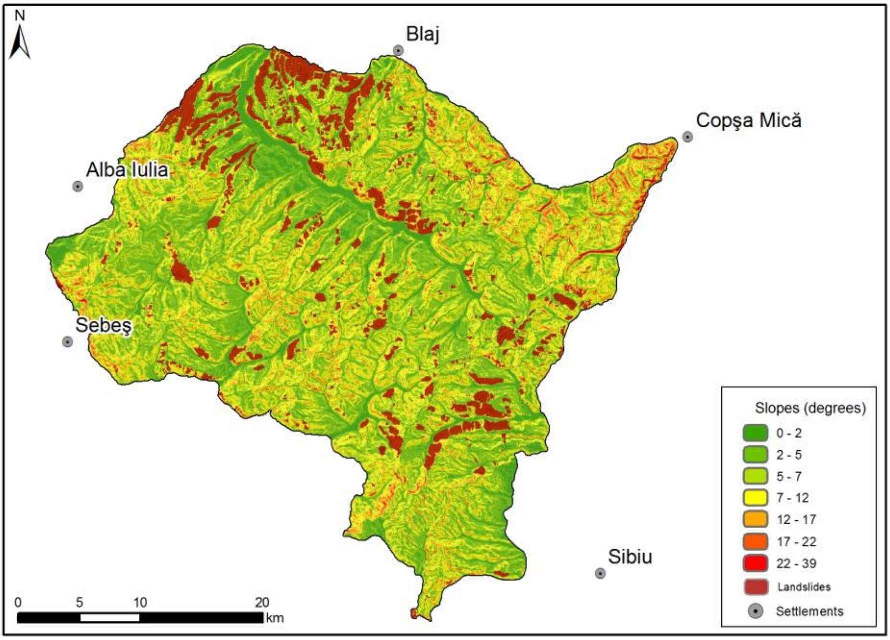

Figure 4. Slope map

The following criterion used for observing landslide distribution is landform exposure to the sun beams (Fig. 5). The exposition decisively determines the heat condition and soil and lithology's humidity, it influences the freezing melting processes, the slopes superficial deposits type and nature, leads to qualitative differences in the processes which are preliminary to the erosion (Jakab, 1979). It can be noticed that the surfaces that have a north-western exposure are affected by the majority of landslides (Table 4). Also, from a surface perspective, the highest values are specific to the northern-western orientations.

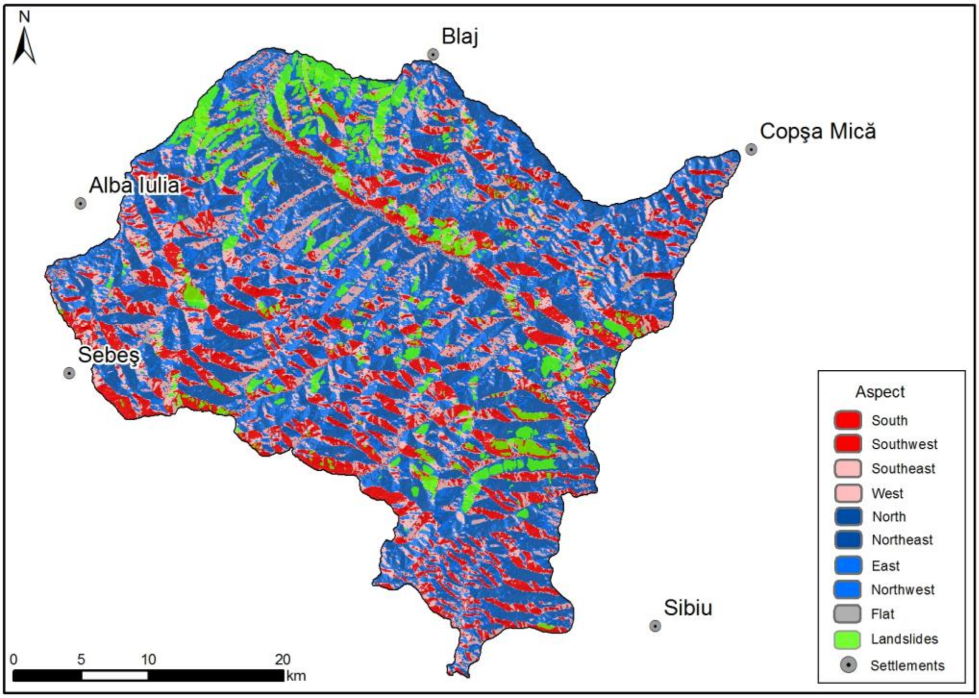

Figure 5. Landform exposure map

Table 4. Landslide distribution based on exposure

Exposuretowards to the sun	Exposure towards Compass irections	Landslide number	Landslide surfaces (ha)	Percentage (%)
Sunny	South	126	1229	11
	South-West	132	1221	11
Partial sunny	South-East	81	1154	10
	West	154	1925	18
Shady	North	88	1273	12
	North-East	42	494	5
	East	55	770	7
Partial shady	North-West	157	2789	26
Flat (unexposed)		0	0	0
Total		835	10855	100

In regards to landslide distribution we took in consideration also the administrative units, for the Secaşelor 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 33 administrative units of which 29 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
Loamneş	9903	1351	14	104
Blaj	6751	1272	19	66
Mihalț	3766	1196	32	29
Berghin	7516	901	12	43
Ocna Sibiului	6589	753	11	30
Crăciunelul de J.	1301	680	52	8
Sântimbru	1527	538	35	17
Roşia de Secaş	5222	509	10	42
Ohaba	4047	450	11	17
Păuca	7360	430	6	38

Table 6. Administrative units landslide distribution by landslide number

Name	Studied territory surface (ha)	Number of lanslide	Landslide surface (ha)	Percentage of the affected surface (%)
Loamneş	9903	104	1351	14
Cenade	4434	103	425	10
Cergău	4819	84	355	7
Blaj	6751	6	1272	19
Berghin	7516	43	901	12
Roşia de Secaş	5222	42	509	10
Șeica Mare	2253	40	100	4
Păuca	7360	38	430	6
Șeica Mică	6037	38	90	1
Şpring	8070	33	372	5

The values showed in Table 6 suggest that even if for some of the territorial-administrative divisions there are a high number of landslides, their surface is relatively small. From a land usage perspective, the most affected landslide categories are represented by agricultural land.

4. CONCLUSIONS

Regarding the landslide type, in most of the cases these are superficial and of medium depth (Varnes, 1978). Their large number is tightly bound, along with the land use, to the geological characteristics. They are Miocene formations which belong to Badenian, Sarmatian and Pannonian. From these for Saramtian, are characteristics the marls, sands and sandy marls and for the Pannonian, clays, sands and poorly cemented grit stones. These clays have comprise minerals such as montmorillonite, illite and beidellite which can retain water. Given that it is a hilly area, made of the above mentioned rocks, the susceptibility to landslides is high.

So, from a spatial distribution perspective, one can conclude that the most affected by landslides are the surfaces overlapped with Pannonian deposits, those on an altitude range of 300-400 m and those which have a slope of 7 – 12^{o}, but also those with a North-Western exposition. At the administrative-territorial unit level the most affected are: Loamneş, Blaj, Mihalț, Berghin, Ocna Sibiului, Crăciunelul de Jos, Sântimbru, Roşia de Secaş, Ohaba, Păuca, Cenade, Cergău etc.

This can be motived by the fact that within the territory of these communes prevail Pannonian deposits, altitude range between 300-400 m and slopes of 7 – 12^{o} angle and also North-Western expositions.

These circumstances require and force actions against landslides within the Secașelor Plateau. Considering the areas susceptibility to landslides, with the combative measures, preventing measures are also necessary. For this matter, we recommend alongside the corresponding necessary agrotechnical techniques and measures to prevent water infiltration of any kind from drainage water, streams or groundwater.

Taking into consideration the high number and the significant areal extent of landslides in the Transylvanian Basin, we consider that it is necessary to continue this type of statistical analysis on other regional subunits of the Transylvanian Basin’s Area. (Transylvanian Plain, Hârtibaciului Plateau, Someşan Plateau etc.).

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