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Original Article

Analysing Landslides Spatial Distribution Using GIS. Case study: Transylvanian Plain

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Abstract

From all the geomorphological processes, specific to Transylvanian Plain, landslides stand out. The mentioned regional unit is placed geographically on the central part of the Transylvanian Basin (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 4.109 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 marns, clays, marl clay) 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. Introduction

One of the main geomorphological processes from Transylvanian Plain is represented by landslides. The Transylvanian Plain is placed in the central part of the Transylvanian Basin, from the proximal units, it is delimitated by valley corridors.

In this regard we distinguish, the Someşul Mare Corridor in the North, Someşul Mic Corridor in the West, Mureş Corridor in the South and, Dipşa and Luţu Valley in the East.

On its 390.362 ha surface 4.109 landslides were identified, which represent 37.359 ha, almost 10% of the entire area.

These are, on one side the result of the geological substrates, and on the other side the result of the lands use which is significantly influenced by the anthropic.

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Under lithological aspect it is especially noticeable the presence of friable rocks like marls, clays, clay marl, gritstone etc., the result of materials eroded and then sedimented from the Carpathian Mountains, which delimitate the Transylvanian Basin [6, 2, 3].

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. And this, given that before the anthropic intervention 90% of the land belonged to the forest, and nowadays, the value is generally under 10% [4]. The forests 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 [5].

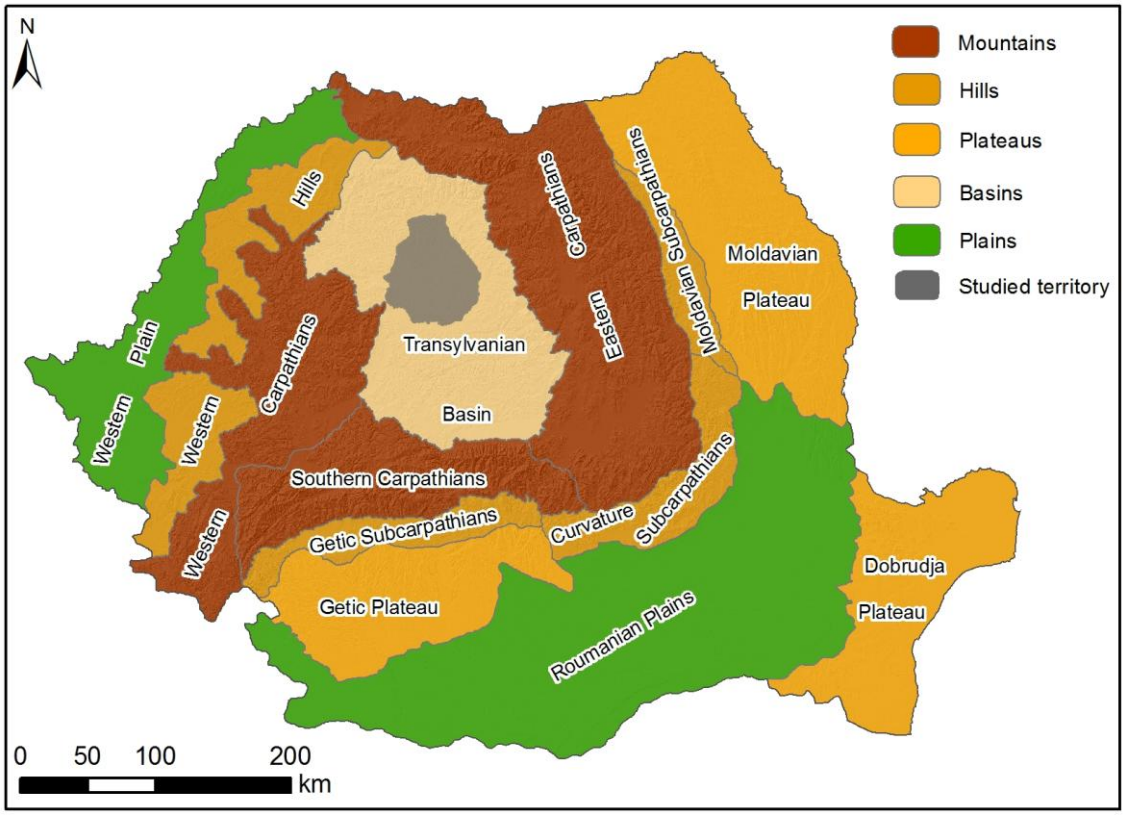

Figure 1. Localization of the study area

Thus, the Transylvanian Plain 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 Transylvanian Plain based on five criteria (geology, altitude, slope, exposure and administrative units), taking into consideration also the field observations.

Landslide identification was made using 1:5000 orthophotos, based on which, using a GIS software (ArcMap 10.22), 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 in order for them 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 Discussions

After vectorizations of landslides from orthophotos, the statistics say that in the Transylvanian Plain, there are 4109 landslides which represent 37.359 ha. Given that the geographic unit surface is of 390.362 ha, it results that 9.57% 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, Badenian (clays, marls, sandstones, tufa), Sarmatian deposits (marl, marly clay) and Pannonian deposits (clay, sand marls) 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.

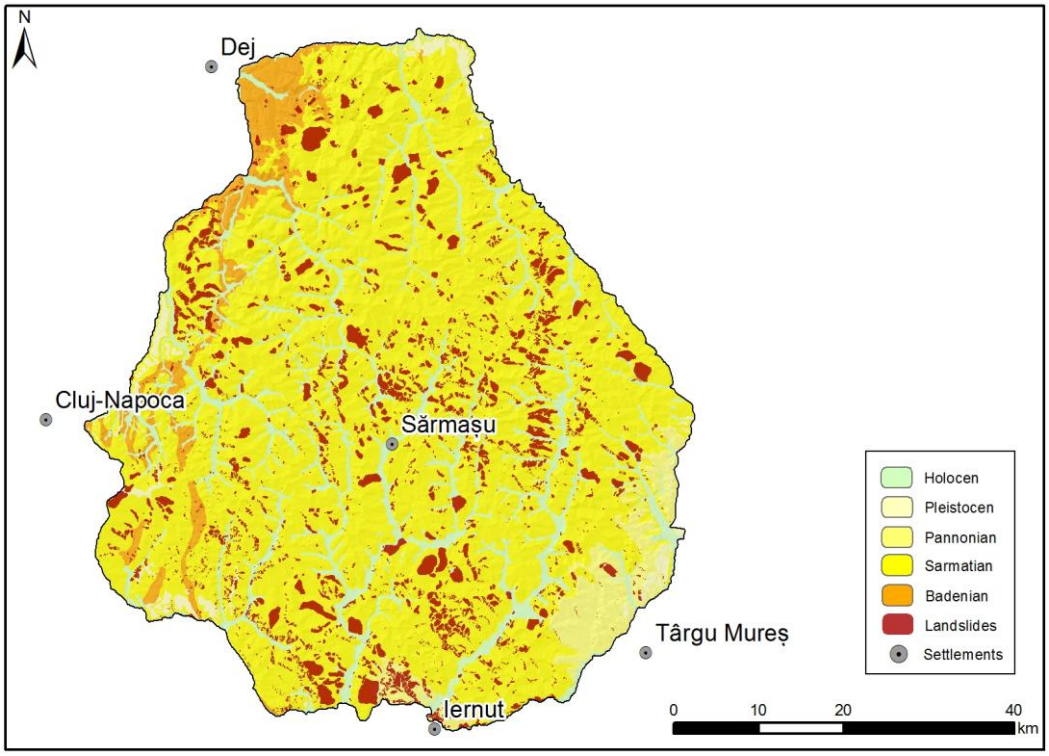

Figure 2. Geological map

Table 1. Landslide distribution based on geological deposits

Geological deposits	Landslide number	Landslide surface (ha)	Percentage (%)
Holocen	167	1324	3
Pleistocen	33	156	1
Pannonian	173	1539	4
Sarmațian	3552	33650	90
Badenian	184	690	2
Total	4109	37359	100

In order to observe landslide distribution from an altitude perspective, five altitude classes were chosen: 232 - 300 m, 300 – 400 m, 400 – 500 m, 500 – 600 m and 600 – 718 m (Fig. 3).

As it results from Table 2, the majority of landslides belong to the altitude range 300 – 400 m and the largest surface is also specific to the 300 – 400 m range.

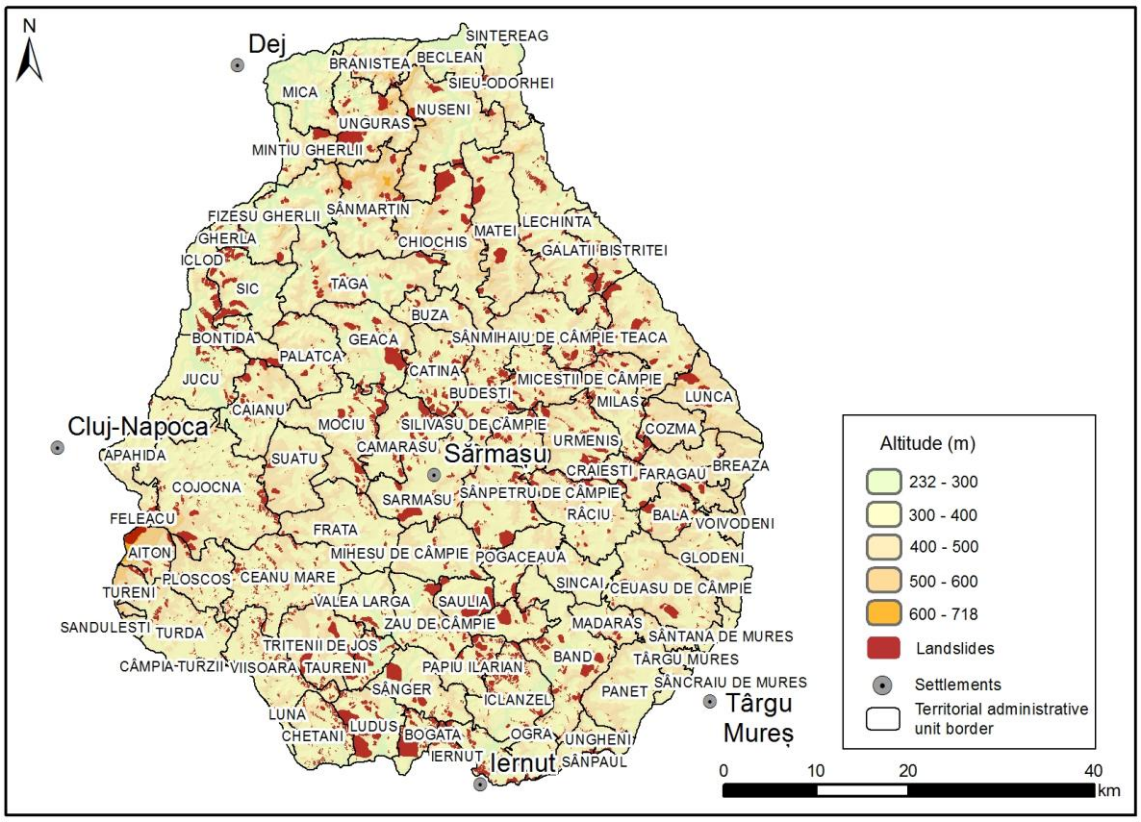

Figure 3. The map of altitude range

Table 2. Landslide distribution based on altitude range

Altitude range (m)	Landslide number	Landslide surface (ha)	Percentage (%)
232 – 300	51	423	1
300 – 400	2827	20927	56
400 – 500	1214	14862	40
500 – 600	16	929	2
600 - 718	1	218	1
Total	4109	37359	100

Another indicator of l andslide distribution is represented by slope. Starting from the previous field classifications depending on slope, for the Transylvanian Plain seven classes were chosen: 0 – 2º, 2 – 5º, 5 – 7º, 7 – 12º, 12 – 17º, 17 – 22º and 22 – 37º (Fig. 4). As it can be noticed on Table 3, the majority of landslides belong to the 7º – 12º slope category and the largest surface is specific to the same range.

Table 3. Landslide distribution based on slope categories

Slope category (º)	Landslide number	Landslide surface (ha)	Percentage (%)
0 - 2	12	820	2
2 - 5	153	6616	17
5 - 7	239	5759	15
7 – 12	1649	15888	43
12 - 17	1438	6733	18
17 - 22	517	1333	4
22 – 37	101	210	1
Total	4109	37359	100

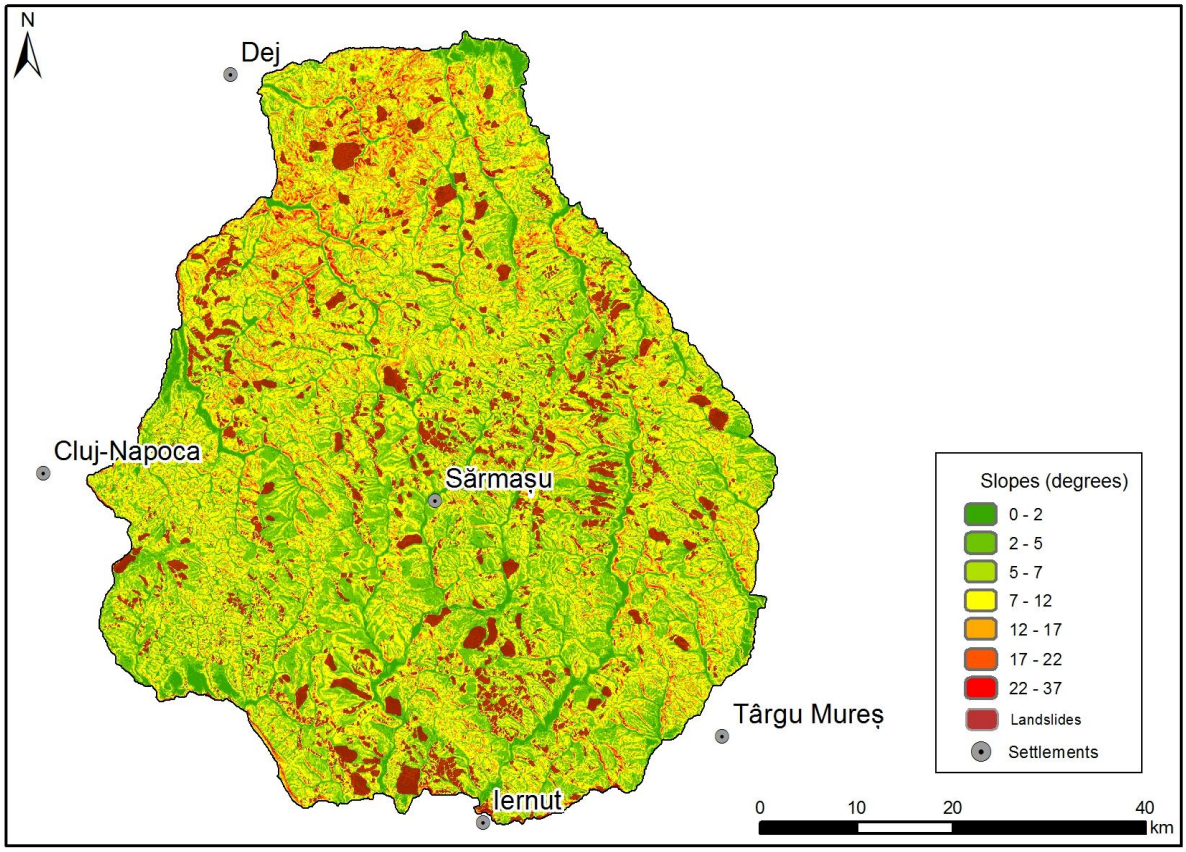

Figure 4. Slope map

An important criterion taken into consideration to observe landslide distribution is represented by slope orientation (Fig. 5).

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 [1]. 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.

In regards to landslide distribution we took in consideration also the administrative units, for the Transylvanian Plain.

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 89 administrative units of which 83 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.

From a land usage perspective, the most affected landslide categories are represented by agricultural land.

Table 4. Landslide distribution based on exposure

Exposure towards to the sun	Expoziţie towards Compass directions	Landslide number	Landslide surfaces (ha)	Percentage (%)
	South	695	6243	17
Sunny	South-West	1183	7711	21
	South-East	331	4728	13
Partial sunny	West	764	5103	14
	North	325	3311	9
Shady	North-East	142	2719	7
	East	168	3681	9
Partial shady	North-West	501	3842	10
Flat (unexposed)		0	0	0
Total		4109	37359	100

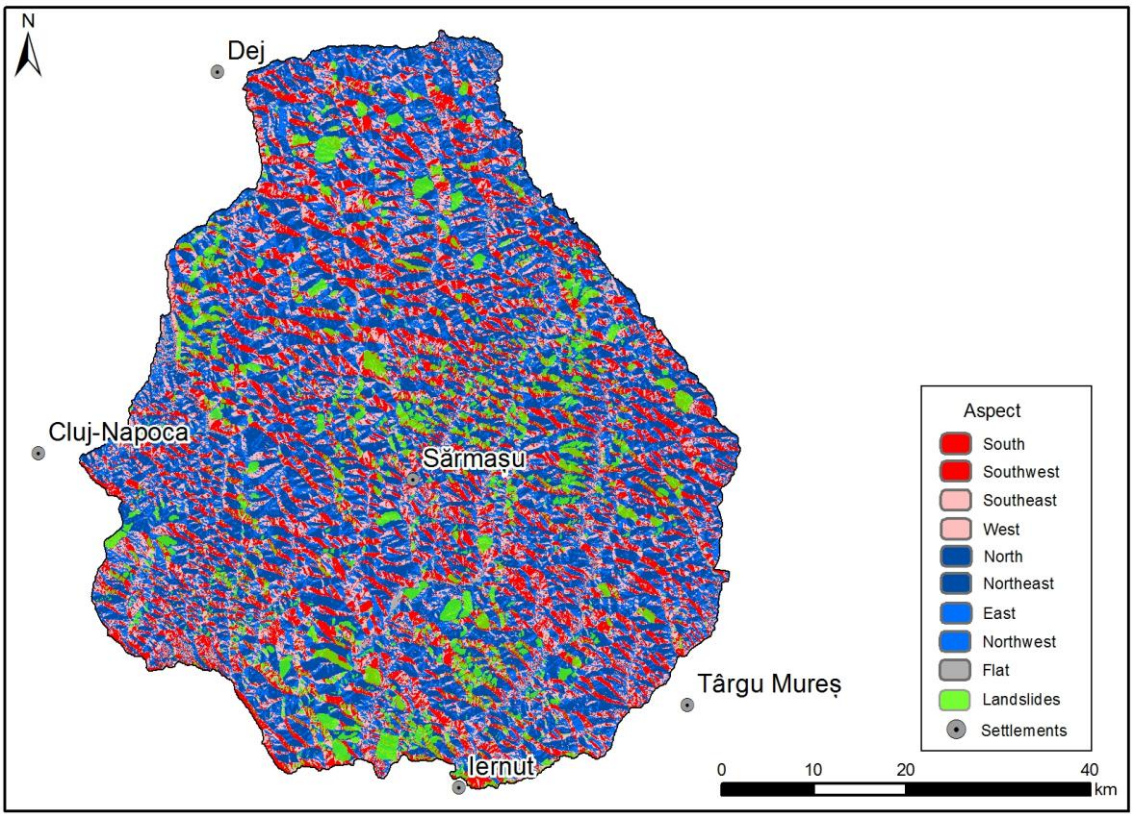

Figure 5. Landform exposure map

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
Urmeniş	5814	1130	19	65
Luduş	4303	1120	26	42
Unguraş	6361	1080	17	53
Iclănzel	6174	980	16	156
Teaca	8556	950	11	64
Chiochiş	9080	930	10	30
Mociu	7254	930	13	89
Bonţida	4596	910	20	25
Ceanu Mare	9607	890	9	254
Bogata	1917	890	46	45

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 (%)
Ceanu Mare	9607	254	890	9
Cojocna	13906	173	800	6
Viişoara	5762	164	510	9
Iclanzel	6174	156	980	16
Band	8999	143	880	14
Râciu	7395	143	810	11
Cheţani	4211	130	450	11
Sânmihaiu de C.	6463	124	720	11
Turda	6145	105	260	4
Lechinţa	10331	102	680	7

4. Conclusions

In regards to landslide type, in most of the cases, these are of a superficial and of medium depth [7]. 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 and Pannonian. For Badenian marls, sands and sandstones are typical, for Sarmatian, marl and marly clays, and for Pannonian, clays and sandy clays. 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 300-400 m and those which have an angle of inclination of 5 – 7 degrees but also those with a South-Western orientation. At the administrative units' level the most affected are: Urmeniş, Luduş, Unguraş, Iclanzel, Teaca, Chiochiş, Mociu, Bonţida, Ceanu Mare, Bogata, Band, Râciu, Cheţani, Sânmihaiu de Câmpie etc. This can be explained by the fact that within these communes territory Sarmatian deposits prevail, altitudes range mainly between 300-400 m, slopes have an angle of inclination of 5 – 7 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 Transylvanian Plain. 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, Hârtibaciului Plateau, Someşan Plateau etc.).

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