# THE USE OF GEOGRAPHIC INFORMATION SYSTEM IN THE EVALUATION AND ANALYSIS OF LANDSLIDES WITHIN THE CALINTIR HYDROGRAPHIC BASIN (REPUBLIC OF MOLDOVA)

**CANȚÎR Angela**

**Abstract.** The paper claims to evaluate landslides in the Calintir River basin (Republic of Moldova), based on data obtained from orthophoto 2016 using ArcGIS 10.4.1 software and ground survey using GPS. For the distribution analysis of this process we used three criteria: slope, altitude and exposure of the slope. This type of studies are necessary to find out how landslides are distributed at the moment within the hidrographic basin and to identify the areas wich are prone to this hazardous geomorphological phenomena. As a result, the following maps for Calintir River basin were created: Landslides, Altitude map, Slope map, Slope exposure map. In addition, it was possible to highlight the share of the areas occupied by processess above mentioned. As the result of this study, knowing the susceptible areas to the geomorphological processess is beneficial for the territorial planning activities and we will have a clear picture, which categories of this morphometric parameters are the most favorable for the appearance of the taken into consideration process and which will be those land surfaces that require increased attention from those who capialize on this territories.

**Keywords:** methods, geomorphological processes, landslides, Calintir river basin, ArcGIS software.

**Rezumat. Utilizarea Sistemelor Informaționale Geografice în evaluarea și analiza alunecărilor de teren în cadrul Bazinului Hidrografic Calintir (Republica Moldova).** Lucrarea pretinde să evalueaze alunecările de teren din bazinul râului Calintir, pe baza datelor obținute din ortofoto 2016 folosind software-ul ArcGIS 10.4.1 și colectarea datelor cu ajutorul GPS. Pentru analiza distribuției acestui proces am folosit trei criterii: panta, altitudinea și expunerea pantei. Acest tip de studii sunt necesare pentru a afla modul în care procesele geomorfologice sunt distribuite în prezent în bazinul hidrografic și pentru a identifica zonele care sunt predispuse la aceste fenomene geomorfologice periculoase. Ca urmare, au fost create următoarele hărți pentru bazinul râului Calintir: alunecări de teren, harta hisposemtrică, harta expoziției versanților, harta pantelor. În plus, a fost posibilă evidențierea ponderii suprafețelor ocupate de alunecările de teren. Ca urmare a acestui studiu, cunoașterea zonelor susceptibile la procesele geomorfologice este benefică pentru activitățile de amenajare a teritoriului și vom avea o imagine clară, care categorii ale parametrilor morfometrici sunt cele mai favorabile pentru apariția procesului luat în considerare și care vor fi acele suprafeţe terestre care necesită o atenţie sporită din partea celor care utilizează aceste teritorii.

**Cuvinte cheie:** metode, procese geomorfologice, alunecări de teren, bazinul râului Calintir, ArcGIS software.

## INTRODUCTION

The Calintir hydrographic basin is located in the south-eastern part of the Republic of Moldova and is one of the right tributaries of the Bîc river (Fig.1), having its sources between the localities of Chetrosu (north) and Geamăna at an altitude of 115 m. The river runs for a distance of approximately 28 km, in the NW-SE direction, and in the town of Balmaz it changes its course to the N. Its catchment area is practically included in the Anenii Noi district and passes through Geamăna, Ciobanovca, Mîndîc, Balmaz, the villages Hîrbovăț and Beriozchi, where it confluences with the Bîc river. It borders seven other hydrographic basins, most of which are part of the Botna basin, only one being a direct tributary of the Dniester. The maximum altitude recorded on the surface of the basin is 220 meters, the territory having altitudes between 100 -150 m.

The soil is the most important natural resource of the Republic of Moldova, but unfortunately not rationally exploited. Although, it represents the resource on which the country's food security and economic potential is based, it continues to be subject to the continuous demands of the people.

From a theoretical point of view, a series of strategies and measures of the rational use of the soil cover are developed. For example, "Soil protection measures within agricultural practices - HG 1157/2008", where measures are presented to prevent physical damage to the soil, measures to prevent degradation and restore soil structure, anti-erosion protection measures for land arable and perennial plantations, measures to combat and prevent landslides and others, but they are rarely applied in agricultural practices. Or they are applied partially and chaotically by farmers. A series of concrete actions were proposed in the "Program of land improvements in order to ensure the sustainable management of soil resources for the years 2021-2025 - HG 864/2020" with the presentation of a concrete action plan for the years 2021 - 2023 in which are included concrete costs and the areas considered for the realization of these actions. Even this program is not fully realized because these costs exceed the financial potential of the state budget. In the end, we can mention the Soil Law, which has been worked on for years, but unfortunately has not yet been implemented and approved.

The pedo-geomorphological processes are continuously expanding very fast (VOLOSCHUK & IONIȚĂ, 2006). This was more pronounced in the central-eastern and southern part of the country, where the hydrographic basin taken as the research territory is also located.The occurrence and distribution of pedo-geomorphological processes depends on several factors: lithology, vegetation, climate, hydrography, relief (with morphometric parameters). Mainly the spread of the processes takes place on the right side of the Calintir river, where most of the degradation processes are concentrated (GUSTAVSSON, 2006; BOJOAGĂ, 2016). Therefore, a more detailed analysis of pedo-geomorphological conditions and processes will be beneficial in the assessment of agricultural land quality.Anthropogenic activity has a strong influence on degradation processes, in most cases, it manifests itself negatively on the condition of the soil cover (URSU & SINKEVICI, 1988).

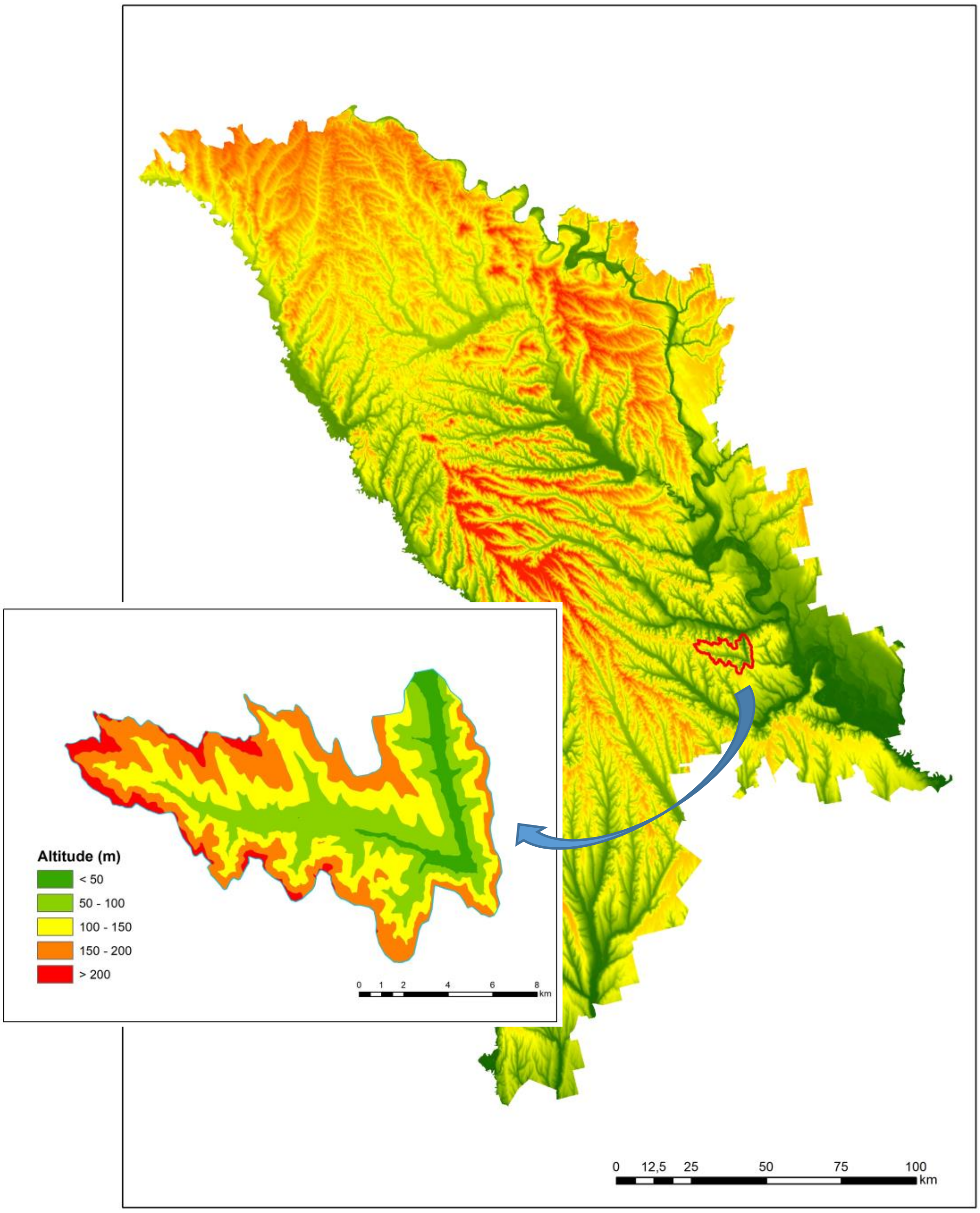


Figure 1. The physical geographical position of the Calintir hydrographic basin
(author processed data using SRTM at 30 m resolution).

Most of the time, land degradation is conditioned by the fact that ecological rules are disturbed and disrupted in improper use through excessive grazing, deforestation, excessive and non-compliant construction of various types, etc. Change of use categories – is one of the most important factors in triggering erosion processes and landslides.In the context of the evaluation and analysis of geomorphological risk processes, in the given case of landslides within the researched territory, a modern technology will be applied in the relief analysis with morphometric parameters and the quantitative and spatial analysis of landslides, using Remote Sensing (satellite images, UAVs, orthophoto) and GIS.

## MATERIAL AND METHODS

Due to the possibility of applying informatics in geography, by means of Geographical Information Systems (GIS) it was possible to map the morphometric parameters of the researched basin and their graphic representation by means of maps. The cartographic support of the Geographical Information System was represented by topographic maps at a scale of 1:25,000 (Fig. 2), based on which the level curves were vectorized at a distance of 5 meters and the absolute maximum altitudes (Fig. 3).

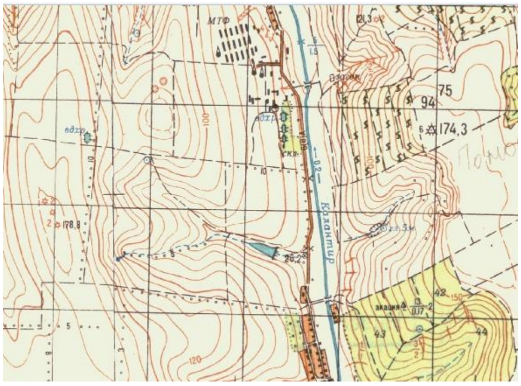

Figure 2. Topograhphic map (scale 1:25 000) (orig.).

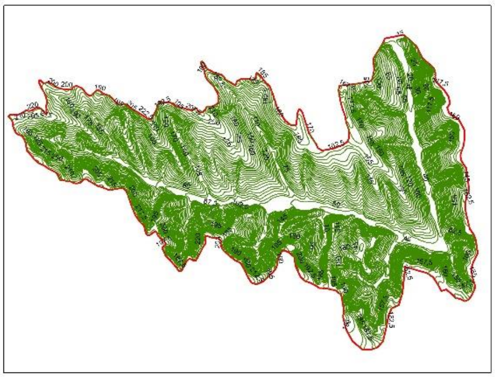

Figure 3. Level curves (scale 1:25 000) (author processed data using vectorized contour lines from topo maps).

For the identification, mapping and analysis of landslides, Orthophotoplans (Fig.4) (MIHĂILESCU et al., 2006) became the initial material for the research, which were supplemented with satellite images (Fig.5), necessary to refine the interpretation results (ZAGAROVSCHI & VOLOŞCHIUK, 2004). Following the interpretation, quantitative indicators of landslides were obtained. The use of remotely sensed data was supplemented and validated with field trips. Vectorization and visualization of map data were done using ArcGIS, MapInfo and Quantum GIS packages. All statistics were calculated using Excel and functions available in ArcTool.

Figure 4. Ortofoto 2020 (rezolution 0,5*0,5).
Source: https://geodata.gov.md

Figure 5. Satellite image Landsat 8 (OLI), 2020.
Source: https://earthexplorer.usgs.gov/

## RESULTS AND DISCUSIONS

Topographic maps gives the primary presentation of relief forms in space and the interdependence (ratio) between them. It provides basic information about the quantitative feature of the relief. In the primary cartographic analysis, topographic maps were used (All maps covering the area of the Calintir watershed) at a scale of 1:25,000, which allow us to analyze and create our own maps and schemes based on them. Deciphering orthophoto planes and satellite images allows us to supplement the data and information collected on the basis of topographic maps and verify their correctness. Deciphering satellite images is a well-known method in the field of remote sensing.

The above mentioned is practically impossible to achieve without using GIS (Geographic Information Systems) technologies. The use of GIS technologies includes a method widely used in science, especially in the field of geomorphology. This method is called the **modeling method**, which includes in itself *cartographic modeling*, which has the ability to render different aspects of the geomorphological processes and the forms created as a result of their activity. The most often used in the modeling of processes and relief forms are *mathematical* and *computer modeling* (JUC et al., 1995; HOFER& FRANK, 2009). Within the analysis of geomorphological parameters, relief forms and the activity of geomorphological processes, computer modeling is increasingly used, that is, the creation of numerical models of the relief, which are generated with the help of level curves or with the help of aerial photographs. With the help of numerical models, some morphometric indices are calculated automatically, in a very short time and with maximum accuracy, with the help of which specific geomorphological maps can be made (BIALI&POPOVICI, 2000; RUDRAIAH et. al., 2008).

The most important processes that contribute to land degradation in the researched territory are specific to the entire territory of the Republic of Moldova and consist of surface erosion, ravines and landslides. After the vectorization of the landslides from the orthophoto, the statistics say that there are 39 landslides in the territory of the Calintir hydrographic basin, which represents 1444.9 ha. Starting from the fact that the total area of the basin is 12440 ha, it follows that the area of landslides has a weight of 11.61% of the total area of the basin.

From the point of view of the distribution of landslides on the surface of the basin taking into account the three criteria taken into consideration, we obtained the following results.The largest share is held by lands with altitudes between 100-150 m. As can be seen from Figure 6 and Table 1, landslides mostly affect lands with altitudes between 150-200 m, and occupy a weight of about 42%. And those between the 100-150 m altitudinal level have a share of about 31% of the total of landslides with an area ofjust over 450 ha. The least affected are the lands with altitudes up to 50 m. According to the data in Table 1, just over 1.5% of the total lands with the altitude up to 50 m, are affected by landslides.

Table 1. Distribution of landslides based on hypsometric map.

| Altitudinal steps (m) | Altitudinal steps (ha) | Landslides (ha) | Share (%) of total landslides | Share (%) of area of each altitudinal step |
|---|---|---|---|---|
| **< 50** | 810,26 | 12,94 | 0,9 | 1,6 |
| **50-100** | 3193,87 | 161,86 | 11,2 | 5,07 |
| **100-150** | 4217,73 | 450,09 | 31,15 | 10,67 |
| **150-200** | 3604,41 | 614,17 | 42,51 | 17,04 |
| **> 200** | 613,73 | 205,84 | 14,25 | 33,54 |

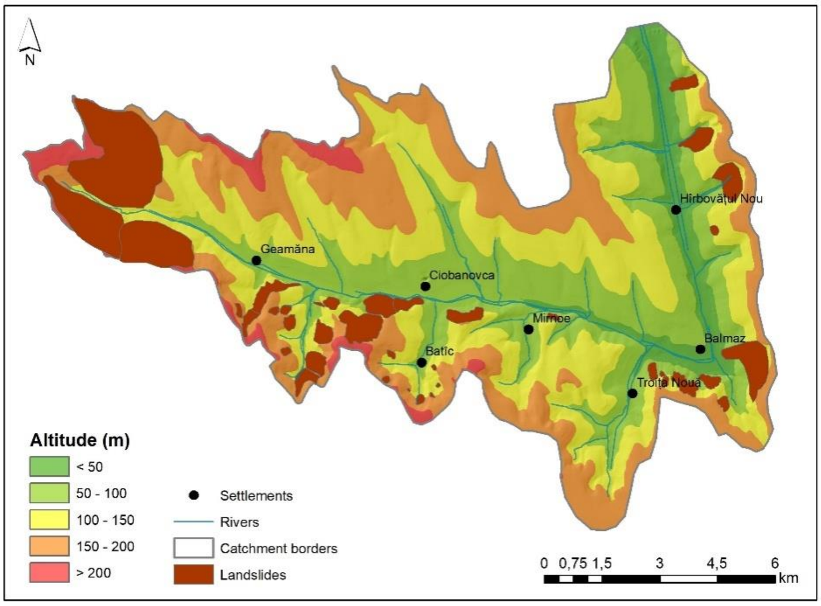


Figure 6. The distribution of landslides on altitudinal ranges (author processed data from ortofoto).

Another indicator used to evaluate the distribution of the sliding process is the slope. Starting from the classification of slopes, we chose to classify them into six classes: 0-2º, 2-5º, 5-7º, 7-9º, 9-12º, > 12º (Fig. 7). As can be seen in Table 2, most of the landslides are developed on the land with a slope between 2-5º, and the largest share belongs, instead, to the class of slopes between 9-12º. This fact is due to the decreasing areas of land corresponding to these categories of slopes (ROSIAN et al.,2018). But it denotes the high probability of the development of landslides, also associated with collapses at the level of the detachment cornice.

Table 2. Distribution of landslides based on slope map.

| Slopes classes(º) | Slopes classes (ha) | Landslides (ha) | Share (%) of total landslides | Share (%) of area of each slope class |
|---|---|---|---|---|
| **0-2º** | 1616,75 | 69,89 | 4,84 | 4,33 |
| **2-5 º** | 4549,21 | 357,36 | 24,73 | 7,88 |
| **5-7 º** | 2710,5 | 309,47 | 21,42 | 11,45 |
| **7-9 º** | 1784,46 | 280,65 | 19,42 | 15,77 |
| **9-12 º** | 1305,15 | 280,65 | 19,42 | 21,56 |
| **> 12 º** | 473,92 | 146,87 | 10,16 | 31,07 |

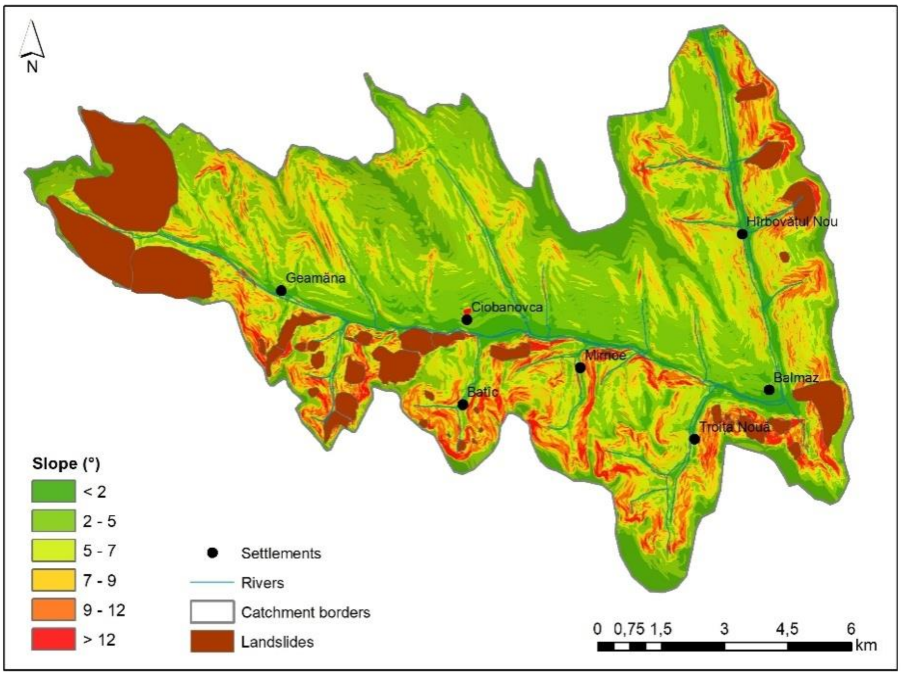


Figure 7. Distribution of the landslides on slope map (author processed data from ortofoto).

The next indicator taken into consideration is the exposure of the slopes (orientation) (Fig. 8). Exposure to solar energy directly influences the occurrence and development of landslides through climatic parameters that are unevenly distributed on the surface: solar radiation, precipitation (DRAGOTĂ et. al., 2008). It is influenced by the freeze-thaw process, soil moisture and due to the type of superficial deposits on the slopes leads to differences in the development of the sliding process (PETREA et al., 2014).

According to Table 3, notice that the surfaces with NE orientation, about 400 ha of landslides, and the highest share of the surface of each exposure class is occupied by the slopes with exposure N (24.79 %) and NW (23.61 %).This is probably due to the fact that these shaded surfaces in combination with the steep slope are favorable to this geomorphological process.The smallest areas affected by landslides are those slopes with exposure E, SE, W, they are also slopes with the lowest share of the surface of these exposure classes.

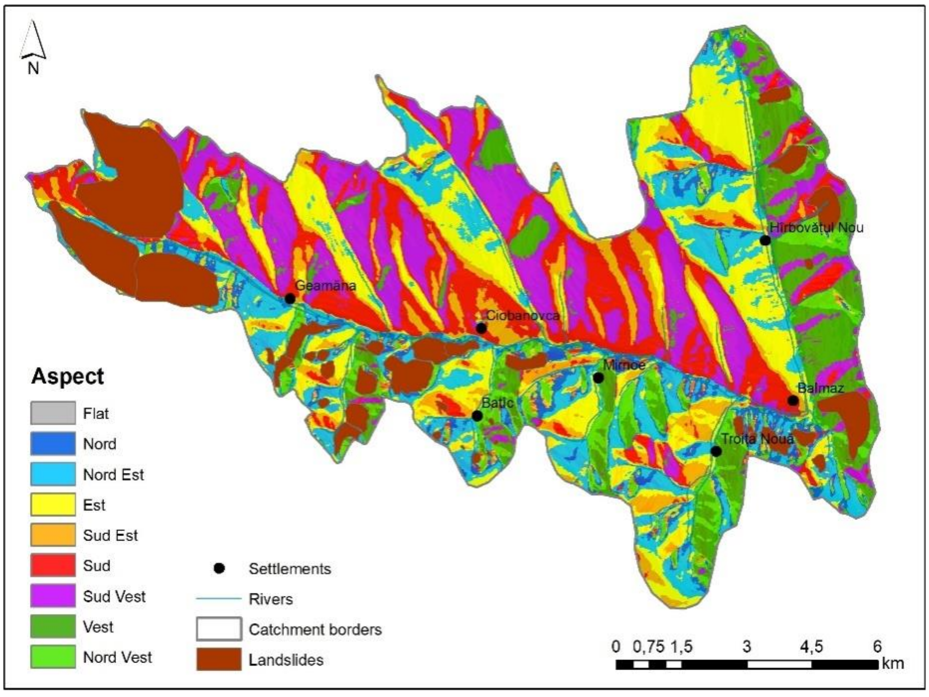


Figure 8. Distribution of the landslides on slope exposure (author processed data from ortofoto).

Table 3. Distribution of the landslides based on slope exposure map.

| Orientation classes | Orientation classes (ha) | Landslides (ha) | Share (%) of total landslides | Share (%) of area of each orientation class |
|---|---|---|---|---|
| **Flat** | 0,00 | 0,00 | 0,00 | 0,00 |
| **N** | 1037,07 | 256,43 | 17,75 | 24,79 |
| **NE** | 2060,03 | 401,07 | 27,76 | 19,52 |
| **E** | 2128,56 | 113,88 | 7,88 | 5,36 |
| **SE** | 1134,40 | 82,00 | 5,67 | 7,25 |
| **S** | 1800,37 | 174,71 | 12,09 | 9,73 |
| **SV** | 2069,46 | 102,60 | 7,10 | 4,97 |
| **V** | 1426,13 | 129,61 | 8,97 | 9,11 |
| **NV** | 783,97 | 184,60 | 12,78 | 23,61 |

## CONCLUSIONS

Due to the usefulness of the Geographical Information Systems and the included tools, it was possible to achieve the MNT together with the morphometric parameters. With the help of the tools, the necessary transformations and calculations were made to form the attribute tables, containing the necessary statistical data. Then they were exported for analysis in Excel, where with the help of calculation formulas we managed to obtain the final data, necessary for the analysis of the researched territory.

With the help of orthophoto plans and topographic maps, landslides were mapped, statistical data was calculated. Their interpolation with the vector layers taken as basic criteria for the analysis of the distribution of landslides found that the most affected from an altitudinal point of view are the surfaces between the altitudes of 150-200 m, being followed with a visible decrease by those between the altitudes of 100-150m.The category of slopes most susceptible to landslides, according to the analysis carried out, corresponds to lands with a slope between 2-5º, and the largest weight belongs, instead, to the class of slopes between 9-12º. And the slopes most affected by landslides, in terms of slope exposure, are those territories with NE, N and NW exposure. This probably has more to do with the retained moisture of the soil water and the presence of slopes greater than 5-7 º.

When all this is taken into consideration together it is clearer which territories from the point of view of the relief are most susceptible to the sliding process and a clearer picture emerges, what would be the most appropriate measures to stabilize these territories for a use as sustainable as possible. From the point of view of stabilizing and reducing the negative impact of landslides on these territories, it is good to take into account a possible change of land use categories, namely on these portions, and if this is impossible, to implement agricultural techniques appropriate in land processing.

## ACKNOWLEDGEMENTS

The research was carried out within the doctoral program Environmental Protection and Rational Use of Natural Resources of the Doctoral School of Environmental Sciences, Moldova State University and within the National Scholarship Programme funded by the World Federation of Scientists in Republic of Moldova

## REFERENCES

BOJOAGĂ I. 2016. Land degradation processes in the catchment of Stemnic river (Buda). *Lucrările Seminarului Geografic Dimitrie Cantemir*.Edit. Universității Al. I. Cuza Iaşi. **42** :39-48. http://dx.doi.org/10.15551/lsgdc.v42i0.04 (accessed December 2024).

BIALI G. & POPOVICI N. 2000. Monitoringul proceselor erozionale pe spaţii întinse cu ajutorul tehnicilor GIS şi analizei spaţiale, *Ovidius University Annals of Constructions*. Edit. Universității Ovidius Constața. **1**(2): 15-25.

DRAGOTĂ C., MICU M., MICU D. 2008.The relevance of pluvial regime for landslides genesys and evolution. Case study Muscel Basin (Buzău Supcarpathians), Romania.*Present Environment and Sustainable Development*. Univeritaria Press. Iași. **2**: 242-257. https://pesd.ro/articole/nr.2/21.%20Dragota_PESD_2008.pdf. (accessed December 2024).

GUSTAVSSON M. 2006. A new symbol and GIS based detailed geomorphological mapping system: renewal of scientific discipline for undestanding landscape development.*Geomorphology*. Elsevier. Paris.**77**(1-2): 90-111; http://dx.doi.org/10.1016/j.geomorph.2006.01.026. (accessed December 2024).

HOFER B. & FRANK A. U. 2009. Composing Models of Geographic Physical Processes, Spatial Information Theory. *9th International Conference, COSIT*. Proceedings Series.Aber Wrac'h Press. Paris. **5756**: 421-435, (online) ISBN 978-3-642-03832-7. https://doi.org/10.1007/978-3-642-03832-7_26. (accessed December 2024).

JUC M., NOVAC Ş., SÎRODOEV Gh. 1995. Modelul numeric de terenului. Determinări geomorfologice. *Lucrările simpozionului "Sisteme informaţionale geografice*. Edit. Univ. "Al. I. Cuza" Iaşi. **1-2**:39-46.

MIHĂILESCU C., SOCHIRCĂ V. Ş.A, CONSTANTINOV T., BOIAN I. 2006. *Mediul Geografic al Republicii Moldova. Resursele Naturale*. Edit. Ştiinţa. Chişinău. 128 pp.

PETREA D., ŞTEFAN B., ROȘCA S., VESCAN I., FODOREAN I.2014. The determination of the Landslide occurrence probability by spatial analysis of the Land Morphometric characteristics (case study: the Transylvanian Plateau). *Carpathian Journal of Earth and Environmental Sciences*. Carpathian Association of Environment and Earth Sciences Published. **9**(2): 91-110. file:///D:/Downloads/Petrea(1).pdf (accessed December 2024).

ROSIAN GH., HORVATH C., MUNTEAN L., MIHĂIESCU R., ARGHIUȘ V., MALOȘ C., BACIU N., MĂCICĂȘAN V., MIHĂIESCU TANIA. 2018. Analysing landslides spatial distribution usig GIS. Case study: Transylvanian Plain. ECOTERRA–*Journal od Environmental research and Protection*. USAMV Press. Cluj-Napoca. **15**(1):27-34. https://www.researchgate.net/publication/347524114_Analysing_Landslides_Spatial_Distribution_Using_GIS_Case_study_Transylvanian_Plain (accessed December 2024).

RUDRAIAH M., GOVINDAIAH S., VITTALA S. S. 2008. Morphometry using Remote Sensing and GIS Techniques in the Sub-Basins of Kagna River Basin, Gulburga District, Karnataka, India.*Journal of the Indian Society of Remote Sensing*. Springer. New Delhi.**36**(4): 351-360. (online). https://link.springer.com/article/10.1007/s12524-008-0035-x (accessed December 2024).

URSU A. F. & SINKEVICI Z.A. 1988. *Soil protection in conditions of intensification of agricultural production*. Moldavian Book Publishing House. Chișinău. 166 pp.

VOLOSCHUK M. & IONIȚĂ I. 2006. *Moldavia, Soil Erosion in Europe*. John Wiley and Sons Press. London., 183 pp.

ZAGAROVSCHI V. & VOLOŞCHIUK M. 2004. *Formele de manifestare a eroziunii liniare şi metodele de combatere, Eroziunea Solului*. Edit. Pontos. Chişinău. 41 pp.

**Canțîr Angela**
Moldova State University. Institute of Ecology and Geography. 1 Academiei street. Chișinău,
MD – 2028, ORCID ID:0000-0001-7014-3486, Republic of Moldova.
E-mail: angelamadan87@gmail.com

Received: January 31, 2025
Accepted: July 13, 2024