Forum Geografic - Studii și cercetări de geografie și protecția mediului (FG - S.C.G.P.M.)

The journal *Forum geografic. Studii de geografie şi protecţia mediului* (Geographical Phorum – Geographical Studies and Environment Protection Research) was founded in 2002, and it seeks to publish high quality research in the domains of geography, environment protection and other related domains. It addresses a range of issues, such as geomorphology, pedology, climatology, hydrology, human geography and environment. Its content is directed to a broad audience, including both academics and policymakers. The papers selected for publication in the journal are subject to a review process using references from universities worldwide.
The journal is currently indexed by the following databases: SCOPUS, DOAJ, EBSCO, ERIH PLUS, Index Copernicus, Scipio, CrossRef, Ulrichsweb, IGU, Google Scholar, WorldCat, ProQuest, ZDB, CNCSIS, DRJI, citefactor.org journals indexing, InfoBase index, Eurasian Scientific Journal Index, ResearchBib.

Cover photo: *Transalpina, Gorj county (Alina Vlăduț)*

For instructions for authors, subscription and all other information please visit our website
http://forumgeografic.ro
before submitting any papers please select the section *Publishing rules* from the About page and read thoroughly the submission instructions for authors

ISSN 1583-1523 (print)
ISSN 2067-4635 (online)
DOI prefix: 10.5775

Instructions for Authors

Article submission

In order to disseminate the research results in the field, researchers, scholars and professionals are welcome to submit an electronic version of the manuscript (in Microsoft Office Word format) to the editorial office (forum.geografic@gmail.com).

Submission requirements: The submission of an article for publication in our journal implies that the article has not been published before, nor it is being considered for publication in other journals. Authors are responsible for the content and the originality of their contributions. In order to be published, articles must be thoroughly researched and referenced.

IMPORTANT: All papers must be submitted in electronic format, only in English language.

Copyright statement

By submitting a scientific work to ***Forum geografic*** the submitters agree to declare the following:

- the submitted work belongs exclusively to the declared authors;
- the submitted work represents original scientific research;
- the submitted work has not been published or submitted for publishing to another journal;
- if the submitted work is published or selected for publishing in ***Forum geografic***, the authors waive any patrimonial claims derived from their authorship for the submitted work; the authors retain the moral rights for their submitted work, as granted under the Romanian applicable law; also, the authors agree to refrain from ulterior submitting of the work to other journals.

The submitters agree to be solely held accountable in case of breaching the above terms and to defend the representatives of ***Forum geografic*** in the event of a lawsuit related to the submitted work.

When submitting a paper the authors are required to print, fill and send a scanned copy of this declaration.

Privacy statement

The submitted personal data, such as names or email addresses, are used only for the declared purpose of the ***Forum geografic*** journal (publishing original scientific research) and are not available to third parties.

Manuscripts are received at all times. However, in order to have your article published in the current year, the manuscripts must be submitted until the 15th of February for the first issue of the current year and until the 1st of September for the second issue.

Article format

All manuscripts must be edited entirely in English. Articles must include:

- Title
- Author's name(s). For each author you must mention the author's scientific title, his affiliation (institution) and e-mail address;
- Abstract (maximum 300 words);
- Keywords (not more than 5-6 words);
- Acknowledgments (if any);
- Main body of text (structured according to Introduction, Data & Methods, Results & Discussions, Conclusions);
- Illustrations (graphs, diagrams, maps, photos – should have indications of their positions in the text and title written in English) must be also submitted in electronic format, preferably in JPG, PNG or BMP format and must be referred to as Figures, which should be numbered with Arabic numbers.
- Tables must be numbered with Arabic numbers and should not repeat data available elsewhere in the text.
- References must be indicated in the text, between brackets and they must include the author's name and the date of the publication (Popescu, 2000). When three or more authors are referred, they will appear in the text as follows: (Popescu et al., 1997). References must be listed in alphabetical order at the end of the text.

The following style sheet is recommended:

- for journals:

Miletić, R., Lukić, V., & Miljanović, D. (2011). Deindustrialization and structural changes in commuting flows in Serbia. *Forum geografic*, X(2), 244-254. doi:10.5775/fg.2067-4635.2011.009.d

- for books:

Bran, F.,Marin, D., & Simion, T. (1997). Turismul rural. Modelul european, Editura Economică, București

- for papers from conference proceedings:

Deci, E. L., Ryan, R. M., (1991), A motivational approach to self: Integration in personality. In R. Dienstbier (Ed.), *Nebraska Symposium on Motivation: Vol. 38. Perspectives on motivations* (pp. 237-288). Lincoln: University of Nebraska Press.

Review process

All the manuscripts received by the editors undergo an anonymous peer review process, necessary for assessing the quality of scientific information, the relevance to the field, the appropriateness of scientific writing style, the compliance with the style and technical requirements of our journal, etc. The referees are selected from the national and international members of the editorial and scientific board, as well as from other scholarly or professional experts in the field. The referees assess the article drafts, commenting and making recommendations. This process leads either to acceptation, recommendation for revision, or rejection of the assessed article. Editors reserve the right to make minor editorial changes to the submitted articles, including changes to grammar, punctuation and spelling, as well as article format, but no major alterations will be carried out without the author's approval. Before being published, the author is sent the proof of the manuscript adjusted by editors. If major revisions are necessary, articles are returned to the author so that he should make the proper changes. Authors are notified by email about the status of the submitted.

FORUM GEOGRAFIC
Forum geografic. Studii și cercetări de geografie și protecția mediului
Volume **XIX**, Issue **2** (**December** 2020), pp. **119-130**
http://dx.doi.org/**10.5775/fg.2017.127.d**

Landslide-susceptibility Analysis, Mapping and Validation in the Bălăcița Piedmont (South-West Romania)

Oana MITITELU-IONUȘ[1], Mihaela LICURICI[1,*] Daniel SIMULESCU[2], Sandu BOENGIU[1], Emil MARINESCU[1]

[1] Geography Department, Faculty of Sciences, University of Craiova, Romania
[2] National Agency for Natural Protected Areas, Dolj Territorial Service, Craiova, Romania
* *Corresponding author*: mihaela.licurici@edu.ucv.ro

Received on 05-03-2020, reviewed on 25-07-2020, accepted on 03-08-2020

Abstract

This work presents the results of applying the GIS matrix method (GMM) to the mapping and validation of landslide-susceptibility analysis in different sectors of the Bălăciţa Piedmont. The main objective of the paper concerns the achievement of landslide-susceptibility maps based on the inventory, classification and description of the landslides within the study area. The starting point was represented by the DEM and, subsequently, based on the lithological data, other determinant factors were analyzed and reclassified in a vectorial format: slope angle, slope elevation and slope aspect. After the factors that determine instability were identified for each type of mechanism, susceptibility maps were drawn. In the resulting landslide-susceptibility map a model for the validation is presented (based on the determination and calculation of a set of landslides not included in the susceptibility analysis). The landslide-susceptibility maps of the Bălăciţa Piedmont are preventive tools intended to minimize risks in the threatened areas, especially near the settlements that are located on the left slope of the Jiu river and witness the reactivation of old landslides.

Keywords: *landslide, statistical analysis, GIS matrix method, susceptibility evaluation, landslide susceptibility map*

Rezumat. Analiza, cartografierea și validarea susceptibilității la alunecări de teren în Piemontul Balaciței (sud-vestul României)

Lucrarea prezintă rezultatele aplicării metodei matricei GIS (GMM) la cartografierea și validarea analizei susceptibilității la alunecări de teren în diferite sectoare ale Piemontului Bălăciței. Obiectivul principal al lucrării se referă la realizarea hărților de susceptibilitate la alunecări de teren pe baza inventarului, clasificării și descrierii acestor procese din zona de studiu. Punctul de plecare a fost reprezentat de DEM și, ulterior, pe baza datelor litologice, au fost analizați și reclasificați alți factori determinanți într-un format vectorial: elevația, aspectul și înclinarea pantei. După identificarea factorilor care determină instabilitatea pentru fiecare tip de mecanism, au fost realizate hărți de susceptibilitate. În harta de susceptibilitate rezultată este prezentat un model pentru validare (pe baza determinării și calculului unui set de alunecări de teren care nu sunt incluse în analiza susceptibilității). Hărțile de susceptibilitate la alunecări de teren în Piemontului Bălăciței sunt instrumente preventive menite să minimizeze riscurile în zonele expuse, în special în apropierea așezărilor situate pe versantul stâng al râului Jiu, unde au loc reactivări ale unor vechi alunecări de teren.

Cuvinte-cheie: *alunecări de teren, analiză statistică, metoda matricei GIS, evaluarea susceptibilității, harta susceptibilității la alunecări*

Introduction

International and national framework

Defined as the movement of a mass of rock, debris, and soil down the slopes (Hungr et al., 2014), landslides are some of the most dangerous geomorphological risk processes, their onset and development being related to some meteorological and anthropogenic factors that have gained increasing frequency and intensity over the past decades. Globally, landslides cause significant (sometimes even catastrophic) socio-economic losses, as well as injury and loss of life (Froude & Petley, 2018; Haque et al., 2019).

On the other hand, in the framework of the practical issues concerning land use planning and mitigation of the negative effects on the population, property, other infrastructure and economic activities, in recent years, scientific research in the field of natural hazards and risks has paid more attention to mass movements and especially to landslides. During the last three decades, numerous international interdisciplinary projects have approached and researched the susceptibility, the hazard and the risk associated with landslides. Thus, an attempt was made to correlate a certain considered result with a working scale, a method and a relevant database (available in terms of quantity and quality). Among the most important projects of this type, which were conducted at European level, there must be mentioned: EPOCH (1991-1993; *Temporal Occurrence and Forecasting of Slope Movements in the European Union*); TESLEC (1996-1999; *The Temporal Stability and Activity of Landslides in Europe with Respect to Climatic Change*); ARMONIA (2004-2007; *Applied multi-risk mapping of natural hazards for impact assessment*); SAFELAND (2009-2013; Living with Landslide Risk in Europe: *Assessment, Effects of Global Change, and Risk Management Strategies*); MATRIX (2010-2013; *New Methodologies for Multi-*

hazard and Multi-risk Assessment) and numerous others (RO-RISK Project, https://gis.ro-risk.ro).

With the adoption of the EU *Thematic Strategy for Soil Protection* in 2006, small-scale assessments of threats affecting soils over Europe, including landslides, received increasing attention. In this framework, the project *Pan-European and nation-wide landslide susceptibility assessment*, supported by the Council of Europe through the Centre on Geomorphological Hazards (CERG), proposed an assessment at continental level, with focus on regional sites, which also included Romania (Günther et al., 2014; Wilde et al., 2018). The project underlined that Romania represents a significant landslide hotspot at European level, with more than 65% of its territory corresponding to mountainous, hilly and tableland units that are prone to a wide variety of landslides. The complexity of landslide forms and processes is induced by the litho-structural parameters of the main relief units, by certain meteo-climatic elements, as well as by the human activity (Council of Europe, www.coe.int). As such, the specialized literature on landslide assessment in Romania, and especially that of the last decade, is of ample proportions (Bălteanu et al., 2010; Micu, 2017; Bălteanu et al, 2020). In this framework, the Bălăciţa Piedmont, a component of the Getic Piedmont, represents a unit significantly affected by geomorphological processes of risk, including landslides characterized by a great morphological, morphometric and morphodynamic diversity (Badea et al, 1976; Stroe, 2003; Boengiu, 2008). The present paper aims at a quantitative assessment of the susceptibility to landslides in the aforementioned unit, respectively an assessment of the spatial distribution of potential landslides in this area. The landslide-susceptibility maps are preventive tools intended to minimize risks in the threatened areas, especially near the settlements that are located on the left slope of the Jiu river and witness the reactivation of old landslides.

Short description of the study area

The Bălăciţa Piedmont represents the western subdivision of the Getic Piedmont, being located in south-western Romania (Fig. 1). The unit under study is an early inhabited space and, at the same time, an area of active development of numerous geodynamic phenomena. These processes are the complex result of favoring (lithology, slopes with declivities above 10º, which are present predominantly on the left side of the valleys, etc.), preparatory (torrential rains after long intervals of aridity or drought, anthropogenic changes in land cover, etc.) and triggering factors.

The area under study covers roughly 260,000 hectares and overlaps with a large number of rural local administrative units, being also connected with three towns located at its border. The total population was about 150,000 people in 2018 (INS, Tempo Online Database).

The separation of the Bălăciţa Piedmont from the adjacent morphological units is as follows: to the north the limit is given by the Motru river with its tributary the Huşniţa; to the east - by the Jiu corridor, from which it is sharply delimited by steep slopes without terraces; to the west by the Danube, and to the south, for the most part the limit is represented by the contact with the Oltenia terrace plain, towards which the limit is both morphological and lithological.

Although some of the field literature highlights more numerous subdivisions at the level of the study area (Roșu, 1959; *Geografia României*, 1992), according to the relief characteristics, the Bălăciţa Piedmont can be divided into three large units: the *Blahniţa and Drincea Plain* (with high limits to the west, north and east, including the Blahniţa and the Drincea catchments, characterized by the pronounced asymmetry of the slopes, the more accentuated vertical erosion and the north - south orientation of the two river courses), the *Desnăţui High Field* (characterized by a weak fragmentation, with wide, tabular interfluves and with numerous river regulation works, including lakes for flood prevention), and the *fragmented Piedmont drained by the Jiu*, with the most active present geomorphological processes (Boengiu, 2008).

The most significant altitudes within the piedmont reveal a general northwest - southeast decline of 2.43 ‰, from circa 360 m, to circa150 m (Fig. 1). The analysis of the relief fragmentation within the Bălăciţa Piedmont shows that this unit is on different evolution stages, the complexity of the fragmentation being closely connected to the maturity degree of the valleys and to the morphogenetic complexes imposed by the paleogeographical evolution (Boengiu, 2008; Boengiu et al., 2010).

Among the natural factors that influence the current dynamics of geomorphological risk processes, the meteo-climatic elements are noteworthy. Thus, the climatic conditions contribute to the modeling of the relief through the thermal variations that destroy the cohesion of the clay rocks from the slope surfaces not covered by vegetation, gradually determining the overcoming of their resistance by the gravitational force. Another even stronger influence is exerted by the precipitation, which has the fastest and widest effects on the triggering and development of the geomorphological risk processes in the Bălăciţa Piedmont. In the framework of an annual amount of 609.7 mm of

Forum geografic. Studii și cercetări de geografie și protecția mediului
Volume **XIX**, Issue **2** (**December 2020**), pp. **119-130**
http://dx.doi.org/**10.5775/fg.2017.127.d**

precipitation recorded between 1961 - 2015 at Bâcleș meteorological station, within the piedmont, the rainiest months are May, June and July (each with over 60 mm of precipitation quantities). Precipitation in the form of high-intensity showers, specific to the spring and summer months, such as those in 1969, 1972, 2005, etc., causes floods that have an increased erosive power and the particularly high solid flow ultimately causes significant deposits.

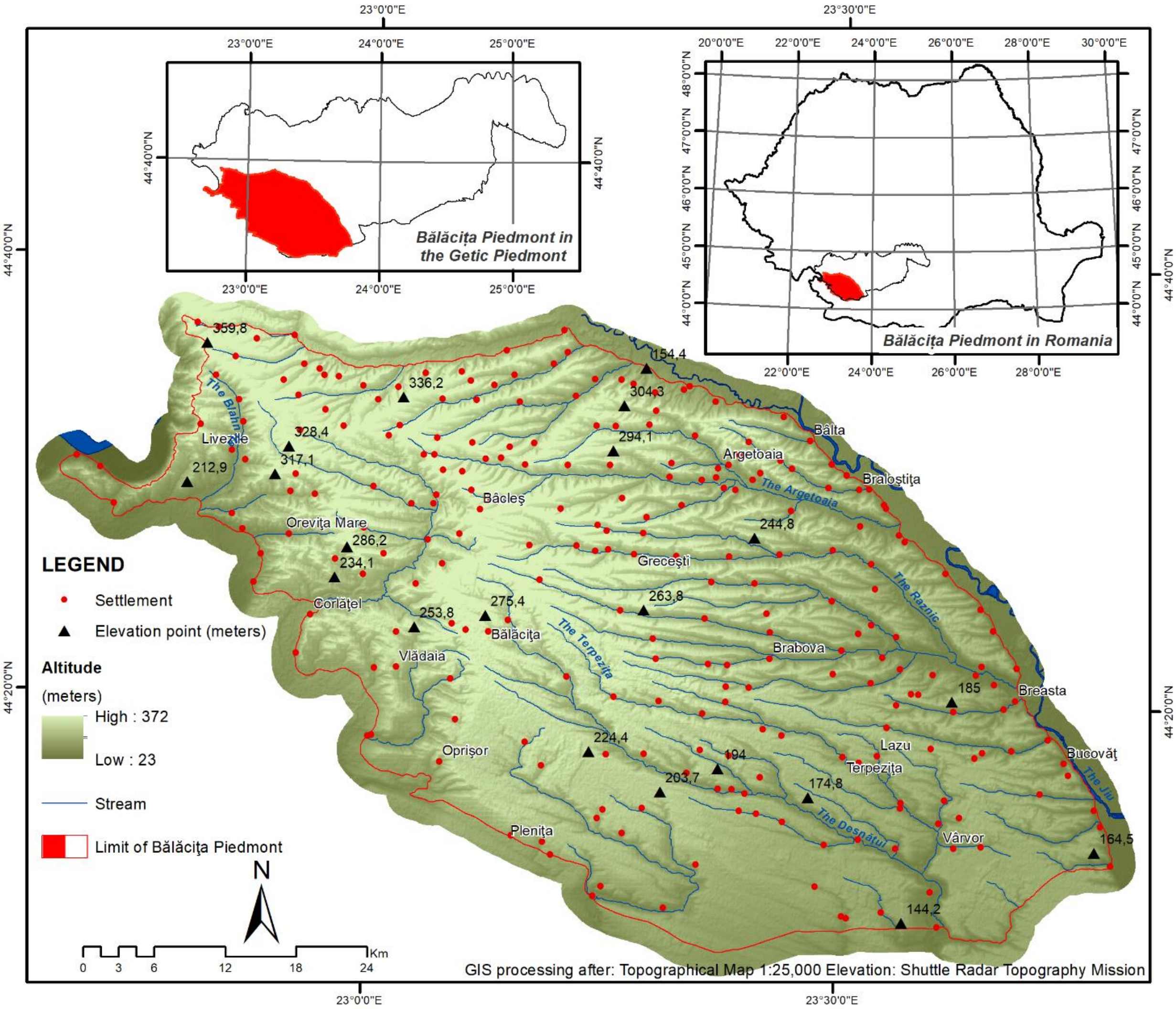


Figure 1: The Bălăciţa Piedmont. Location and hypsometry

The hazardous geomorphological implications of these torrential precipitations are even more pronounced when they occur after arid/dry periods, which damage the vegetative cover and cause cracks. From this point of view, the most problematic months are July and August. The field literature documents the showers registered on July 12th, 1999, when 150mm/36 h were registered in Strehaia Piedmont, or those occurring on July 1st and 2nd, 2005, when 101.7 mm were registered at Bâcleș meteorological station (215.9% above the normal monthly average), 130 mm at Breasta, and 103.5 mm at Filiași (Mărinică, 2006; Boengiu et al, 2012).

Along with these elements, there must be mentioned the role of groundwater runoff and accumulation at the base of sandy deposits that stand on impermeable clayey or marly rocks, which contribute to the initiation of mass movement processes and especially of landslides. The rise in groundwater levels after the rapid snow melting or heavy rains sometimes increases the groundwater stress on deluvial deposits and causes material displacement on the slopes.

On the background of certain particular lithological and morphographic elements that favor the occurrence of landslides, there is to be noticed an increased influence of climate change effects and of the anthropogenic impact in the development of these processes within the Piedmont (Fig. 2, Fig. 3).

The human-induced land use/land cover changes (such as the deforestation for the expansion of agricultural fields, occurred especially during the 19th century, or the uncontrolled felling in the post-1989 transition period, which sometimes took place even on previously stabilized plots, such as those at Radovan), contributed to landslide development or reactivation.

Figure 2: The Bucovăț landslide (photo by S. Boengiu, 2006)

Figure 3: The Argetoaia landslide (photo by S. Boengiu, 2008)

Other anthropogenic factors favoring landslides can be also added, such as the expansion of compacted and built surfaces, unsustainable agricultural practices, the decrease of slope stability through various forms of excavation, etc. As a result of significant changes in land use/ land cover, most of the surface of the Piedmont belongs to the agricultural domain; the non-irrigated arable land holds 56.4% of the entire surface, being predominantly extended in the western half of the study area. To this category there are to be added the heterogeneous agricultural surfaces mixed with natural vegetation (5.1%), the complex cultivation areas (4%), the vineyards and orchards (3.6%). The deciduous forests, which account for 15.2% of the surface, cover more important surfaces in the north and southeast of piedmont (CLC 2012).

Thus, the man-induced changes had significant influences upon the environment and especially upon the relief, the increased vulnerability of the terrains to the dangerous geomorphologic phenomena being one of the important problems that the local communities have to face nowadays (Ionuş et al., 2011).

Data and methods

The most significant vector in the spatial analysis is represented by the existing landslides (the analyzed period being 2006-2016, when the old landslides were monitored and their reactivation after the rainy years). In this regard, the landslide matrix relies on a previously geo-referenced landslide database of the region, in which the slopes are distinguished into two simple classes: with or without landslides.

In order to develop the spatial analysis model, we used the statistic GIS technique based on the bivariate probability analysis equation proposed by Yin & Yan (1988), Jade & Sarkar (1993) and Fernandez et al. (2003) at international level, as well as by Bilașco et al. (2011, 2013) and Bălteanu et al. (2020) in Romania.

$$I_i = \log\frac{Si/Ni}{S/N}$$

Where:

Ii – statistical value of the i factor

Si – area with identified landslides within each considered variable

Ni – area of the analyzed variable category within the studied territory

S – total area affected by landslides within the studied territory

N – the study area in square kilometers.

The basic data in the inventory is provided by the source areas related to each landslide, this being appropriate for detailed scale maps (1:25,000). Information concerning lithology, vegetation, thickness of superficial deposits, and maximum precipitation in 24 h, average annual precipitation, geological contact, faults and proximity to flow channel was also used. The next step of the methodology consists in analyzing the influence of each individual variable on the way landslides occur.

The favorability function described by Chung and Fabbri (1999) is based on the quantification of landslide probability, the dependent factor being represented by the spatial distribution of landslides. The determinant factors expressed in raster format were reclassified and transformed into a vectorial format, and were generalized by classes, in order to attain a simpler attribute table for the map (Table 1).

The statistical analysis of the elevation grid highlights a high value (2.87) on the elevation comprise between 305.1 – 363 meters. The geodeclivity influences the appearance of landslides,

Forum geografic. Studii și cercetări de geografie și protecția mediului
Volume **XIX**, Issue **2** (**December 2020**), pp. **119-130**
http://dx.doi.org/**10.5775/fg.2017.127.d**

a phenomenon supported by statistical analysis by value of 2.05 corresponding to an inclination ranging a value greater than 25.57 degrees.

The general direction of the slopes of the Bălăcița Piedmont relief is statistically supported by the following values: North – 1.56 and South 1.55. The lithological feature is one of the geological variables worth considering. The statistical analysis From the statistical analysis of this determining factor in the occurrence of landslides, it results that these types og geomorphological processes occur mainly on sedimentary rocks and poorly consolidated sands (1.63 and 1.69). Land use and land cover reflect the human interventions in the natural landscape. The database used in the spatial analysis and for the statistical values results was derived from the vector structures of the Corine Land Cover 2012. The statistical values highlights that the vegetation changes induced slope instability and interfered in the landslide reactivation.

Precipitation influences the landslides rate and temporal distribution. For the study area there were used precipitations from five meteorological stations (D.T. Severin, Bâcleș, Craiova, Băilești and Calafat). The highest values comprised between 605 mm and 622 mm correspond to the highest statistical value of 1.108.

Table 1: Computed statistical values for the GIS model variables

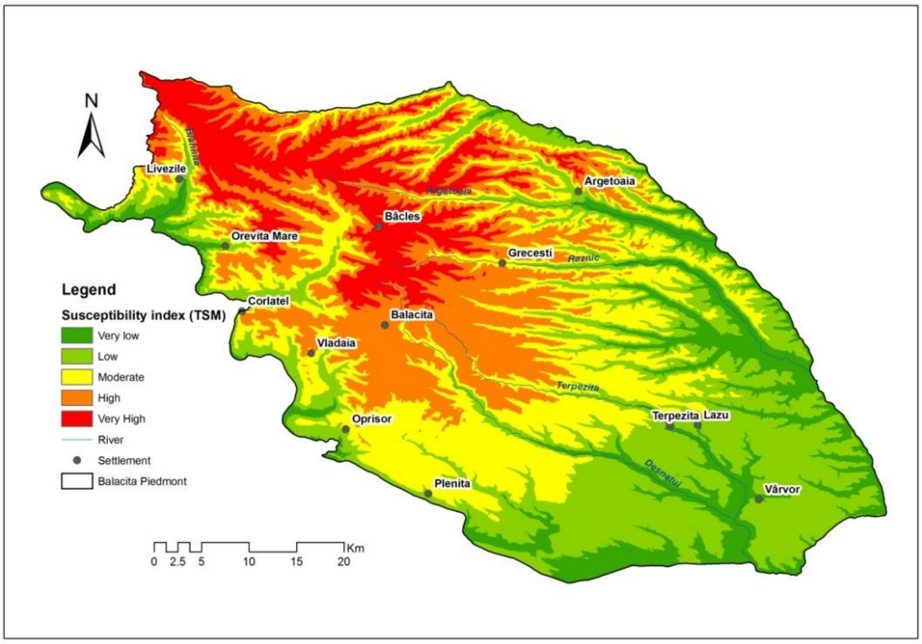
Variable	Characteristic intervals	Statistic value	Variable	Characteristic intervals	Statistic value
Elevation	55-118 118.1-144 144.1-165 165.1-186 186.1-207 207.1-229 229.1-252 252.1-277 277.1-305 305.1-363	2.52 2.19 1.94 1.96 1.89 1.65 1.73 1.90 1.91 2.87	**Lithology**	qh2 p qp2-qp3 lv qp1 qp3/3 qp2/3 qp2/2 qp1/3	0.07 1.63 -1.47 1.69 0 0 0 0 0
Slope (degrees)	0-2.98 2.99-7.27 7.28-11.29 11.30-14.67 14.68-17.65 17.66-20.25 20.26-22.72 22.73-25.57 >25.57	1.48 0.94 1.24 0.65 1.61 1.61 1.78 1.83 2.05	**Corine Land Cover**	Urban fabric Industrial or commercial units Non-irrigated arable land Vineyards Fruit trees and berry plantations Pastures Complex cultivation patterns Heterogeneous agricultural areas Broad-leaved forests Mixed forest Natural grasslands Transitional woodland-shrub Water courses	-0.68 -0.11 -0.7 0.12 0.2 0.66 -0.001 0.18 -0.07 2.83 0.74 0.097 1.39
Aspect	Flat North Northeast East Southeast South Southwest West Northwest North	1.22 1.56 0 0 0 1.55 0 0 0 0	**Precipitation**	479-505 506-522 523-536 537-548 549-559 560-566 567-574 574-587 588-604 605-622	-1.108 -0.82 -0.43 -0.33 -0.09 -0.0 0.016 0.35 0.67 1.108

Further, the main stages in the development of the landslide-susceptibility model are: modeling the matrix of the total surface of the study area (TSM), modeling the landslide matrix (LM), modeling the susceptibility matrix (SM) and validation of susceptibility maps. The Raster Calculator function makes possible the integration of all raster to be grouped into one.

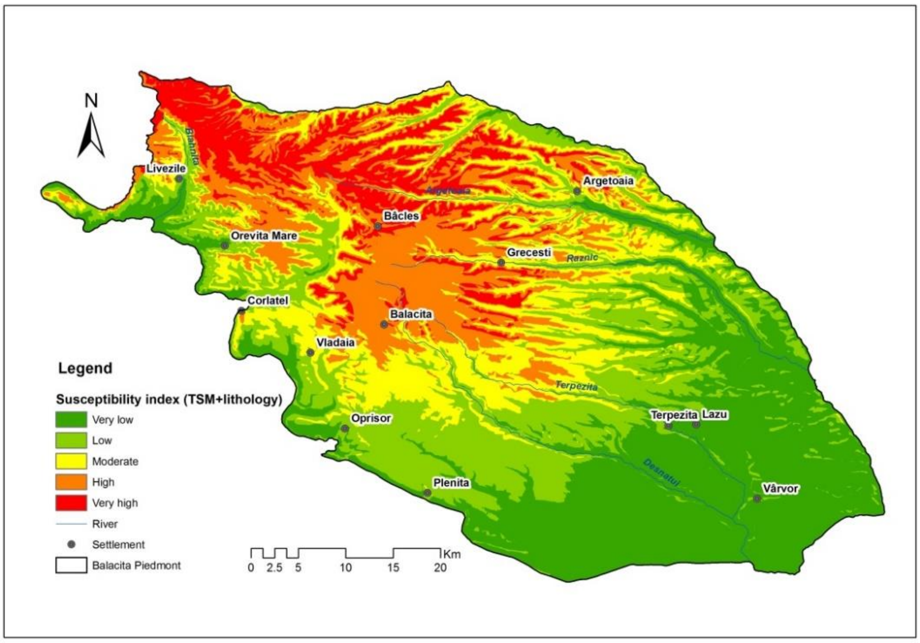
Results and discussion

GMM (GIS matrix method, developed by Jiménez-Perálvez et al., 2009) has been applied to landslide susceptibility analysis, mapping and validation. The starting point was represented by the DEM and the other determinant factors were delivered, analyzed and reclassified in a vectorial format: slope angle, slope elevation and slope aspect (resulting the TSM susceptibility). After the factors that determine instability were identified for each type of mechanism (in our case the lithology, the land cover and the precipitation), susceptibility maps were drawn (Fig. 4 - A, B, C, D).

Inserting all the determining factors in the appearance and reactivation of landslides, it is observed the reduction of the manifestation area of these geomorphological processes in the northern part of Bălăcița Piedmont. The representative areas for the very high susceptibility class (value class between 14.33-23.28) are identified north of Bâcleș settlement, while areas with high susceptibility (value class between 11.13-14.32) and moderate susceptibility are overlapping the Argetoaia and Raznic river basins (Fig. 4 - D).

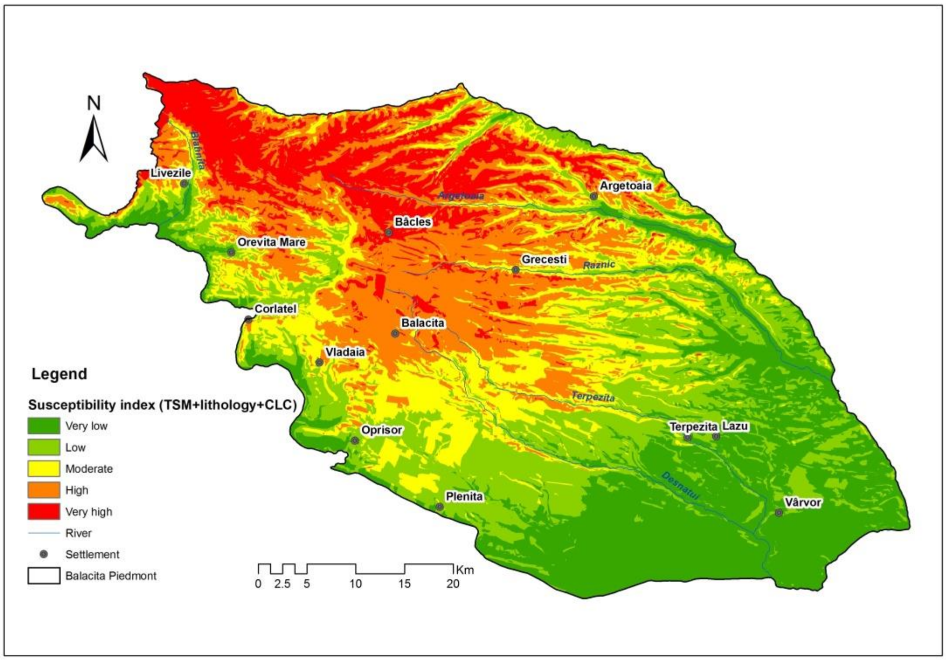


A

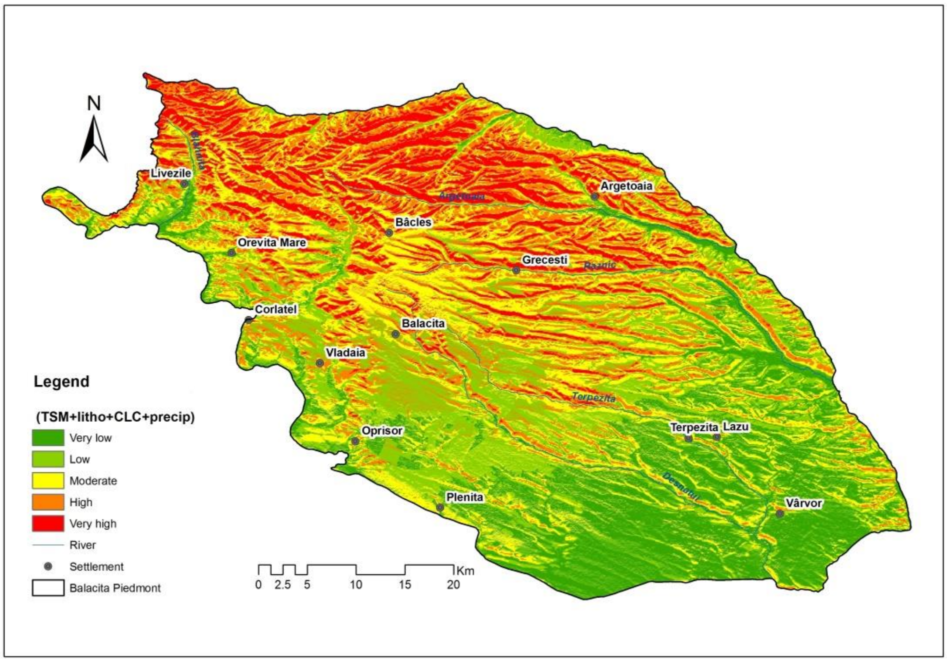


B

Forum geografic. Studii și cercetări de geografie și protecția mediului
Volume **XIX**, Issue **2** (**December 2020**), pp. **119-130**
http://dx.doi.org/**10.5775/fg.2017.127.d**



C



D

Figure 4: Landslide susceptibility map of the Bălăciţa Piedmont: A.TSM susceptibility; B. TSM and lithology; C.TSM, lithology and Corine Land Cover (2012); D. TSM, lithology, Corine Land Cover and Precipitation

The higher the percentage, the more susceptible is the corresponding combination of factors to landslide phenomena. The maps were drawn to include a classification divided into five categories: very low, low, moderate, high and very high using the natural-breaks method (Table 2).

This method identifies break points by selecting the class breaks that best represent the similar values and maximizes the differences between classes. The extent of each susceptibility level depends on the relief and the type of process considered. The values indicate that the final map (TSM, Lithology, CLC and Precipitation) is not conservative, but rather that it limit the zones of maximum susceptibility just to the relatively reduced area where the associated combination of factors exist. The values indicate that the final map (TSM, Lithology, CLC and Precipitation) is not conservative, but rather that it limit the zones of maximum susceptibility just to the relatively reduced area where the associated combination of factors exist.

Table 2 Susceptibility classes and values of the landslides-susceptibility matrix methods

Susceptibility classes	Terrain susceptibility (TSM) -values-	TSM and Lithology -values-	TSM, Lithology and CLC (2006) -values-	TSM, Lithology, CLC and Precipitation -values-
Very low	3-4	1.50-4.69	0.82-4.11	0.75-5.22
Low	4-6	4.70-6.63	4.12-5.92	5.23-8.20
Moderate	6-8	6.64-8.00	5.93-7.55	8.21-11.12
High	8-10	8.10-9.69	7.56-9.32	11.13-14.32
Very high	10-12	9.70-12.63	9.33-13.29	14.33-23.28

Source: own computation after processing susceptibility index map

The percentage analysis of the susceptibility classes highlights, for the entire study area, values of over 20% for the areas classified as being with very low, low and moderate susceptibility, their extension being in the center, western, southern and partially eastern part of the Bălăcița Piedmont (Fig. 5).

The high susceptibility has a value of almost 20%, the areas corresponding to this category being the most dispersed at the study area level. Although they correspond to the lowest percentage value (11.62%), the surfaces with very high susceptibility to landslides have the highest concentration in terms of localization.

The final results highlight the fact that there is an acceleration trend of landslide processes in the high susceptibility area.

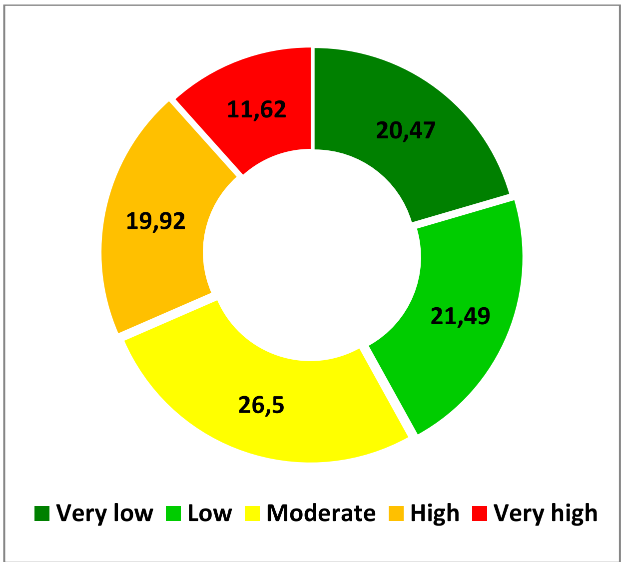


Figure 5: Frequency histogram for each susceptibility level

A main stage in the development of models, procedures or methodologies consists in the validation/evaluation process, which allows the quantitative assessment of its quality.

The model validation was achieved by similar research and field observation on very high susceptibility areas within the Bălăciţa Piedmont.

In Romania, a high percentage (10–30%) of the high and very high susceptibility classes occur on hills and tablelands developed on sedimentary rocks (Transylvanian Depression, Moldavian Plateau, Moldavian Subcarpathians and Getic Piedmont) (Bălteanu et al. 2010).

Landslide agglomerations, in different states of activity, (re)activated during a single landslide event or pertaining to different generations, are a characteristic of the Getic Piedmont (Jurchescu, 2014). In this region the relatively large distribution of terrains with high landslide susceptibility in the region can be confirmed by the abundant landslides (5 landslides/100 km2). (Bălteanu et al. 2020).

The diverse topographical arrangement in the Bălăciţa Piedmont is locally disturbed by other basement block movements. One example of this is the reflection of the Strehaia-Bâcleş-Vidin Uplift in the relief (Boengiu and Avram 2009). In Figure 6, the Strehaia-Bâcleş-Vidin structure is represented through the isobaths describing the contact between the Dacian-aged formations of Berbeşti and Jiu-Motru (Enciu 2007). The corresponding topography is given by a flat interfluves, 5 to 7 km wide.

The drainage model in this sector has an outward direction, with the Motru river righthand tributaries flowing towards NE (the Slătnic, Rocşoreni and Bălţaţi streams), the right tributatries of the Jiu river flowing east (the Raznic and Tejac streams), the Drincea stream flowing west and the Desnăţui stream - firstly directed east, then south following the Lom-Băileşti–Filiaşi depression (Enciu et al. 2006, 2007) (Fig. 5). This locally radial drainage configuration has accordingly ordered slope aspects and thus controls the landslide distribution.

Forum geografic. Studii și cercetări de geografie și protecția mediului
Volume **XIX**, Issue **2** (**December 2020**), pp. **119-130**
http://dx.doi.org/**10.5775/fg.2017.127.d**

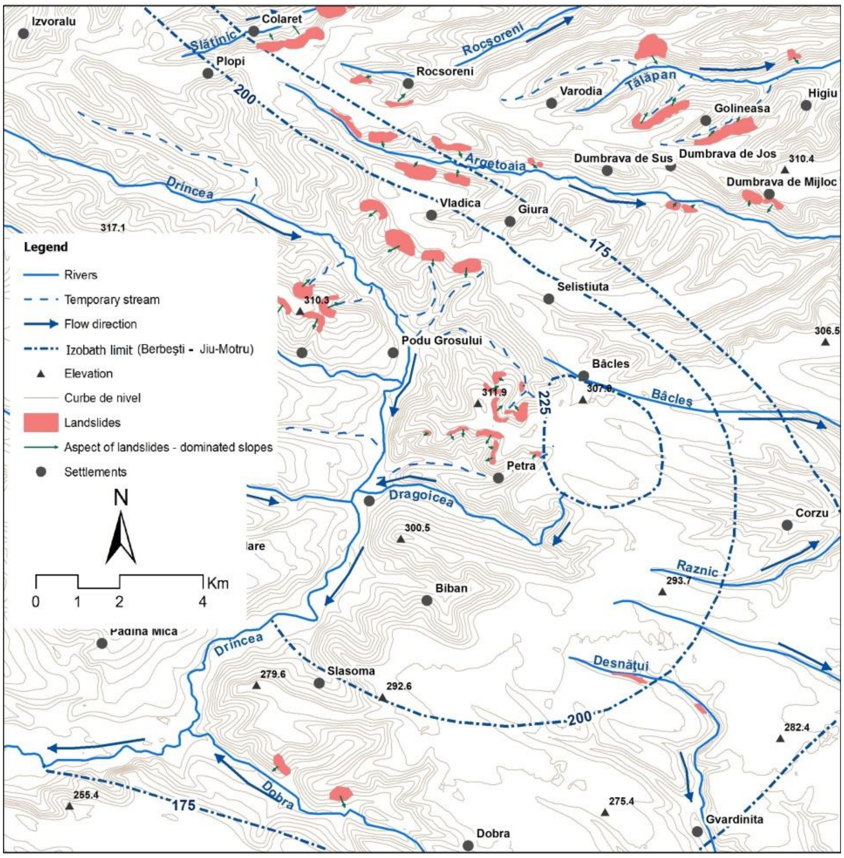


Figure 6: Structural - geomorphological connections in the Podu Grosului - Bâcleş sector (Bălăciţa Piedmont) (processing after Enciu et al., 2006)

The purpose of the field research was to identify landslides by direct observation, and then to compared the results with the modeled database (Irigaray et al., 2007).

The landslide-susceptibility maps are preventive tools intended to minimize risks in the threatened areas, especially near the settlements that are located on the left slope of the Jiu River and witness the reactivation of old landslides.

The Breasta landslide is located at the confluence of Jiu and Raznic rivers, on the right slope of the Jiu River, that has a high altitude and a steep slope (Fig. 7). This landslide was triggered by the bank erosion enhancement by the Jiu River, due to many years of excessive rainfall and always had sectors that were reactivated in the years with higher amounts of rainfall.

The steep toe of the landslide at the contact with the Raznic riverbed offers the premises of an active lateral erosion that leads to the undermining of the slope and, in the end, to the reactivation of this sector of the landslide. In the 2006-2016 analyzed period, it was noticed the reactivation of this landslide, in the spring of 2011, generated by the maximum precipitations registered in 24 h.

In 2011 the western sector of the Breasta landslide was reactivated. In this area, the lack of vegetation led to the dislocation of the sedimentary material in a significant amount. The material carried by the landslide in the Raznic riverbed was washed and transported into the Jiu River. In the central part, that is less forested, the attenuated slope and the extension of the Raznic floodplain, determined a much slower sliding of the sedimentary material. Also in this area, the appearance of small ponds can be noticed at the contact of the slope with the Raznic's floodplain. In the upper part of the eastern sector it is partially forested, which gives it a better stability (Fig. 8).

The occurrence and the effects of the landslides can be prevented and reduced by:

- the drainage of the water accumulated and coming from the landslide;
- the afforestation of the slope, especially the reactivated part of the landslide;
- restrict the pasturage in the area;
- elevate the protection dam from the Jiu river and elevate and lengthten the remu dam on the Raznic river;
- in case of flood it is recommended to make a breach in the protection dam from the Jiu river provided that the level of the water in the Jiu river is not high;
- inform the inhabitants in the area about the danger of a possible flood and about the measures to be taken in case of flood.

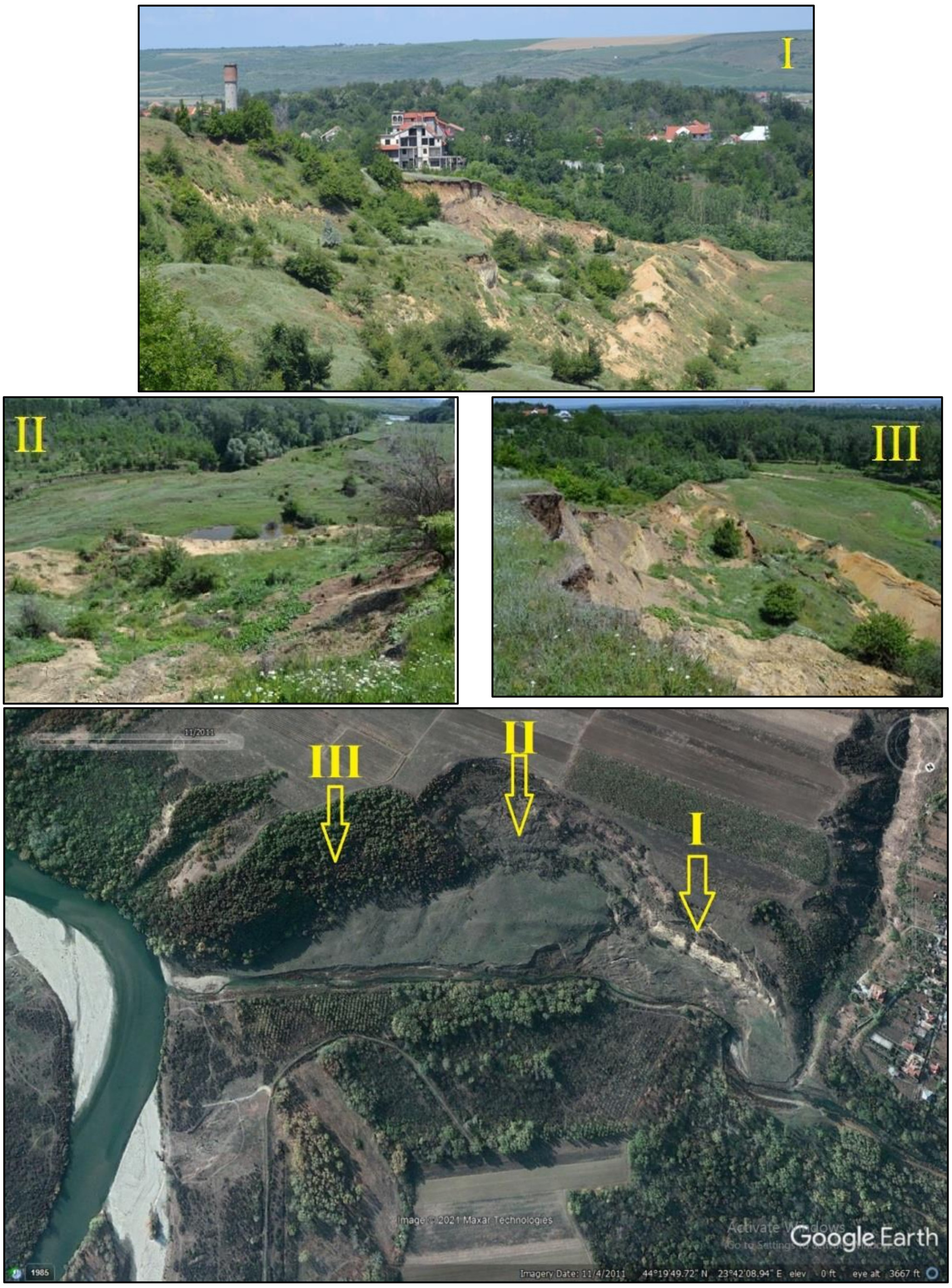


Figure 7: The Breasta landslide reactivation in 2011 (Source - Google Earth PRO, photos by D. Simulescu)

Conclusion

The current study presents an approach for drawing the landslide susceptibility map in agreement with European methodological framework and Romanian morphostructural specific, climatic and land use conditions.

The GIS spatial analysis model supports extrapolation to other territories being an example to consider regarding the validation of the results. The advantage of the methodology used is given by the fact that it is perfectly suitable for development within a Geographic Information System. Instead, the disadvantage is that the quality of the final maps obtained depends on the landslide inventory and the built-in control factors.

Once the landslide susceptibility map is drawn and validated, it is possible to make a simple and quick selection of areas where more detailed studies would be necessary. Thus, an important aspect of the study area consists in the future correlation of