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Article

The Landslides within the Lower Bic Plain (Republic of Moldova): Typology and Spatial Distribution

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Abstract. The Lower Bic Plain is located in the southeast part of Moldova, occupying a total area of 2663 km². Geology, relief, climate, hydrography, vegetation and especially human intervention, which occur in this region, led to the deployment of geomorphological processes on extremely large surfaces. Among the processes prevailing on the territory of The Lower Bic are landslides, affecting about 2138,03 ha of the total area of the investigated territory. Typology analysis and spatial distribution of the landslides on the territory of the plain was conducted under a geomorphologic inventory of the affected areas by this process. For identification, mapping and analysing these processes topographic maps (scale 1:25 000), geological maps (scale 1:200 000) and ortophotoplans of 0,5 m resolution (2007 edition) were consulted, using MapInfo 9 and Arc GIS 9.3 software and also field observations. The spatial distribution of landslides reveals their higher prevalence in the NS direction with a rare spread to NW and SE. Even though many degraded areas were improved through anti-erosion work, performed until 1990, conditions have been created that led to the resumption of geomorphological processes.

Keywords : landslides, types of landslides, spatial distribution

Résume. La plaine du Bic inférieur est située dans la partie sud-est de la Moldavie, occupant une superficie totale de 2663 km². La géologie, le relief, le climat, l'hydrographie, la végétation et surtout l'intervention humaine qui caractérisent cette région ont conduit au déploiement de processus géomorphologiques sur des surfaces extrêmement grandes. Parmi les processus prévalant sur le territoire du Bic inférieur on trouve les glissements de terrain, affectant environ 2138,03 ha de la superficie totale du territoire étudié. L'analyse typologique et l'analyse spatiale des glissements de terrain sur le territoire de la plaine ont été menées dans le cadre d'un inventaire géomorphologique des zones touchées par ce processus. Pour l'identification, la cartographie et l'analyse de ces processus, des cartes topographiques (échelle 1:25 000), cartes géologiques (échelle 1: 200 000) et orthophotoplans de résolution 0,5 m (édition 2007), ont été consultés, en utilisant les logiciels MapInfo 9 et Arc GIS 9.3 ainsi que des observations sur le terrain. La répartition spatiale des glissements de terrain révèle leur prévalence plus élevée sur la direction N-S avec une propagation rare vers NV et SE. Bien que de nombreuses zones dégradées ont été améliorées par des travaux anti-érosion qui ont été effectués jusqu'à 1990, les conditions de la reprise des processus géomorphologiques ont été créées par la suite.

Mots clés : glissements de terrain, types de glissements de terrain; répartition spatiale

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Introduction

One of the most important geomorphological processes, transforming the surface of the slope in the field are landslides.

In order to understand more deeply the significance of the slip process we will give examples of definitions proposed by specialists in the field. Practically, in all the bibliographic sources of the specialists, the term „landslide” or „mass displacement” have the same meaning. For example, in geomorphology, the authors Donisa and Boboc (1994) define the sliding term as „the process of moving the material on the slopes or several slip surfaces soaked with water”. Another definition of the term „sliding” is the detachment of materials (rocks or slope material) that move along a planar surface (Rădoane et al. 2006). But one of the most complex definitions is the one introduced in the „Encyclopedia of Ecology”, where the author defines the landslide as „the dislocation and displacement of a mass of rocks on a sloping surface that is strongly moistened and plastic, usually composed of clays and marne” (Dediu, 2010). Regardless of where the term landslide is used, generally the meaning is the same: moving a solid material from a sloping surface.

Various researches have been carried out in the central region of the Republic of Moldova (Codrilor Bîcului Plateau) and in the northern part of the Republic (Bilinkis and Drumea, 1978; Sîrodoev and Boboc, 2019), and data on the specificity of landslides are systematized in the above-mentioned works (Levadniuk, 1990). A detailed classification of landslides according to different criteria is described in the work ‘’Natural Hazards” (Volontir et. al., 2008). In this paper, author present the classification of landslides according to 5 classification criteria, adapted based on the conditions and type of landslide development on the territory of the country.

Further, this study will present information on types of landslides that exist in the investigated territory and the spatial distribution of this significant process, which plays a very important role in assessing the state of the relief. The main purpose of this article, in fact, is to exemplify the typology of landslides (developed based on the stability criterion) within the field and their spatial distribution, taking into account the character of the stability of the territory.

1. Study area

The Lower Bic plain is located in the central-eastern part of Moldova (Figure 1). Its area is about 2282 km^2 and includes, totally or partially, the basins of Bic, Botna, Baltata and Calintir rivers.

From the morphometric point of view, the relief of the plain has small-medium hills and valleys, with the orientation from northwest to southeast. The north western part is bordered by Codrii Bicului Plateau, the north eastern and the eastern part by the Lower Dniester Plain, the south-south eastern part is bordered by the Cogilnic

Plain and the south-south western part by the Middle Cogilnic Plateau. The slopes of the basins within the territory of the plain have over 160 m altitude and the length of the slopes often exceeds 1000 meters. Only the interfluves between Botna – Dniester and their tributaries are represented by crests that exceed 160 m, its maximum altitude being of 223,8 m and the average altitude of 122,2 m, while the minimum does not exceed 6,4 m (Figure 1).

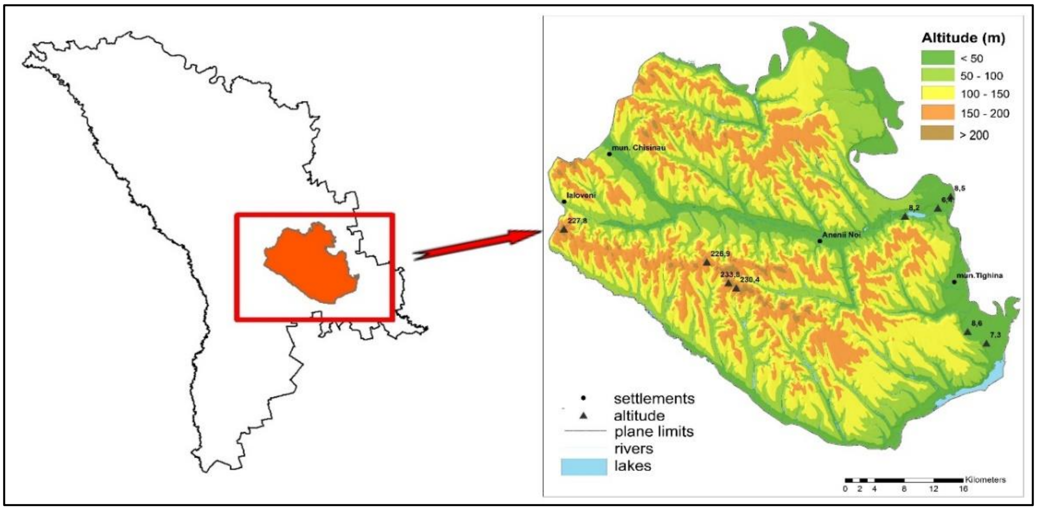

Figure 1. Location within the Republic of Moldova and the relief of the Lower Bic Plain

The relief of the plain is sculpted by numerous flowing waters forming valleys and depressions specific to this type of relief (Donisă and Boboc, 1994).

The hypsometric map (Figure 1) highlights 5 altitude steps and the histogram of the surfaces by hypsometric classes (Figure 2) represents the same 5 classes by percentages in the total area of the territory (Canțîr, 2016).

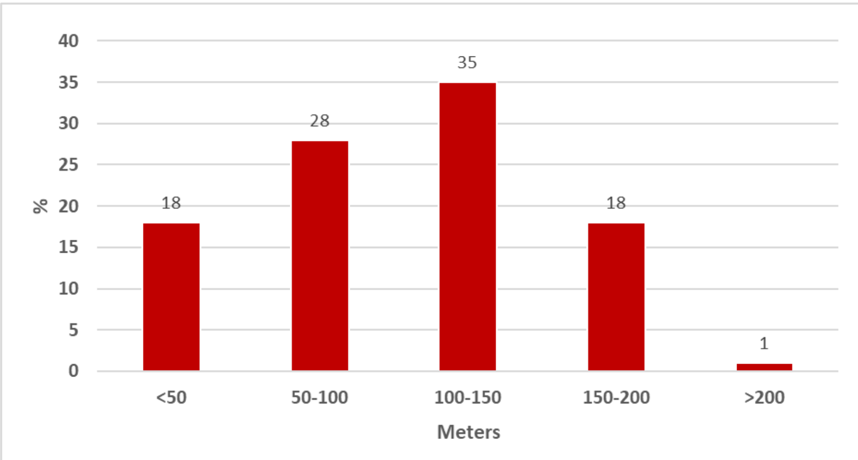

Figure 2. Histogram of surfaces by hypsometric classes (m)

2. Methodology

For the identification, mapping and analysis of the landslides, topo-maps at the 1:25000 scale, geological maps at the 1:200000 and orthophotoplans with a resolution of 0,5 m were used (2007 edition) (Figure 3,4).

With the help of GIS technologies, which include methods widely used in science, especially in the field of geomorphology, we have had the opportunity to reproduce different aspects of the geomorphological processes and the forms created by their activity. Practically, all elaborated maps are made with the help of MapInfo 9 and ArcGIS 9.3 programs. In the analysis of the geomorphological parameters of the geomorphologic processes activity, we used the computer modelling (Hofer et.al., 2009), thus creating the numerical model of the terrain and then calculating the morphometric indices.

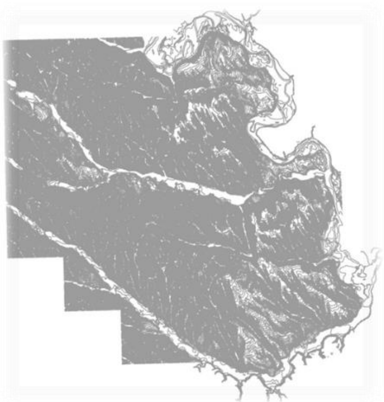

Figure 3. Contour lines (scale 1:25 000) **Figure 4**. Orthophotoplans (resolution 0,5x0,5)

The map of the landslides processes was created, and the main parameters (sliding surface, the type of the landslide, etc.) of the sliding process were analysed. The elaborated structure of the database and the data available in this database allowed to obtain statistical data regarding the sliding process, for example the sliding surface and the type of the landslide according to the criteria we were interested in. All statistical data were calculated using the Excel program.

3. Results and discussions

The most important geomorphological process, along with gullies and surface erosion, that contribute to the degradation and modeling of the surface of the relief of the Lower Bic Plain are the landslides (Mihăilescu et.al., 2006).

The classification of the landslides type is made according to certain criteria (Mițul et.al., 2000), namely: the depth of the sliding surface, the character of the mass of the rock mass, the speed of sliding, the shape of the sliding body and the character of stability. According to these criteria we distinguish between several types of landslides. For example, for the analysis of the landslides within the Lower Bic Plain the classification of landslides according to the character of stability will be used. Thus, according to this criterion, the landslides are divided into two categories: active and stabilized (Figure 5-8).

Figure 5. Landslide near the village of Colonița

Figure 6. The main scarp of a landslide

Figure 7. Main scarp of the landslide

Figure.**8.** Active landslide (Unmanaged garbage)

After the 1970s and the beginning of the 1980s, land registers began to appear on ravenous lands and on those affected by landslides, but these data included the central regions of the Republic of Moldova, which are most susceptible to such processes. Referring to our research territory, only partially, the situation regarding the condition of the affected surfaces was reflected in cadastre.

An attempt was to present a dynamic of the slides using the 1: 5000 topographic planes of the 80s and the orthophotoplanes (0.5 m resolution), but due to the lack of topographic plans throughout the plain this was not possible, being necessary to mention that this is erroneous. Consequently, only orthophotoplanes (0.5 m resolution) were used, without presenting their dynamics. Thus, with the help of orthophotoplanes, 211 active and stabilized landslides were identified (Table 1), their total surface representing 2138.03 ha.

Table 1. The surface of the landslides

Landslides	Number	Surface (ha)	% (from the total slip)	% (from the total plain Surface)	Smin (ha)	Smax (ha)	Smed (ha)
active	109	737,88	34,51	0,32	0,23	50,50	6,77
stable	102	1400,15	65,49	0,61	0,52	117,79	13,73
Total	211	2138,03	100,00	0,94	0,23	117,79	10,13

Source: After orthophotoplanes, 1: 5000, 2007

The number of stabilized landslides is about the same as the number of active landslides, but as surface they almost double the surface of the active landslides. The minimum surface area of a landslide in the plain is 0.23 ha, and the maximum area is 117.79 ha (this is a slope that is practically affected by the slip process and is also called a sliding slope). The average area of a landslide is 10.13 ha.

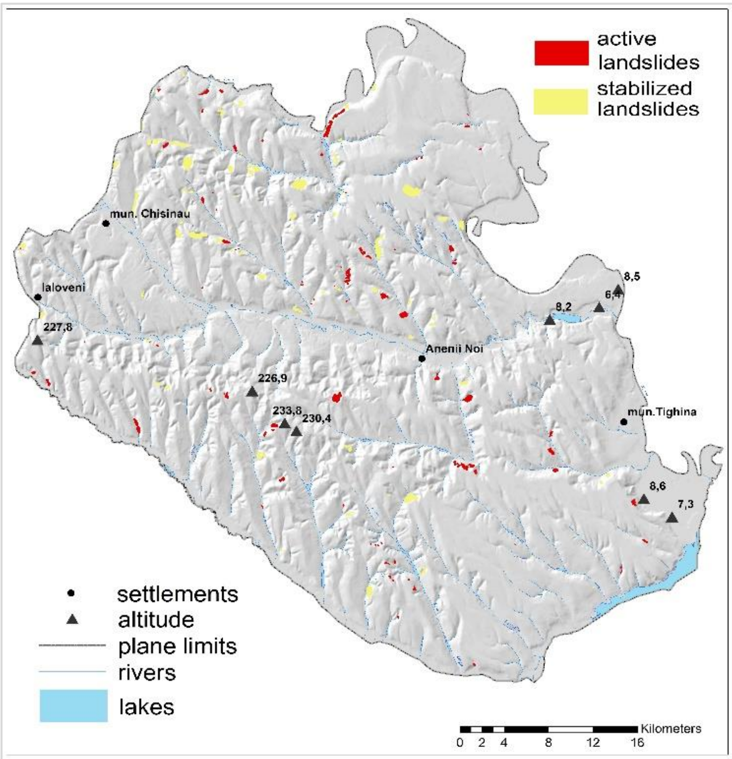

Figure 9. The distribution of landslides within the Lower Bic Plain

The distribution of landslides in the investigated territory is not uniform. Most landslides are recorded on the slopes of the plain, so these processes are more concentrated in the N-S direction with a rare distribution to NV and SE (Figure 9). Altitude is an important factor in triggering the sliding process. Figure 10 shows a graphical representation of the landslides association with the altitudinal steps. A high frequency of active landslides, over 12% and 16%, is recorded in the altitude range of 100-150 m and respectively in that of 50-100 m. Instead, at altitudes less than 50 m, only 6.23% of the landslides occur, of which 2.73% represent the active ones, while the stabilized ones are only 3.5%. The largest stable landslides are found at altitudes between 50-150 m and hold a share of over 50%. The lowest value is registered on the altitude class of over 200 m, which occupies a share of less than 1% of the total landslides, but here a higher share, about 7 times higher, is represented by the active landslides (Figure 10).

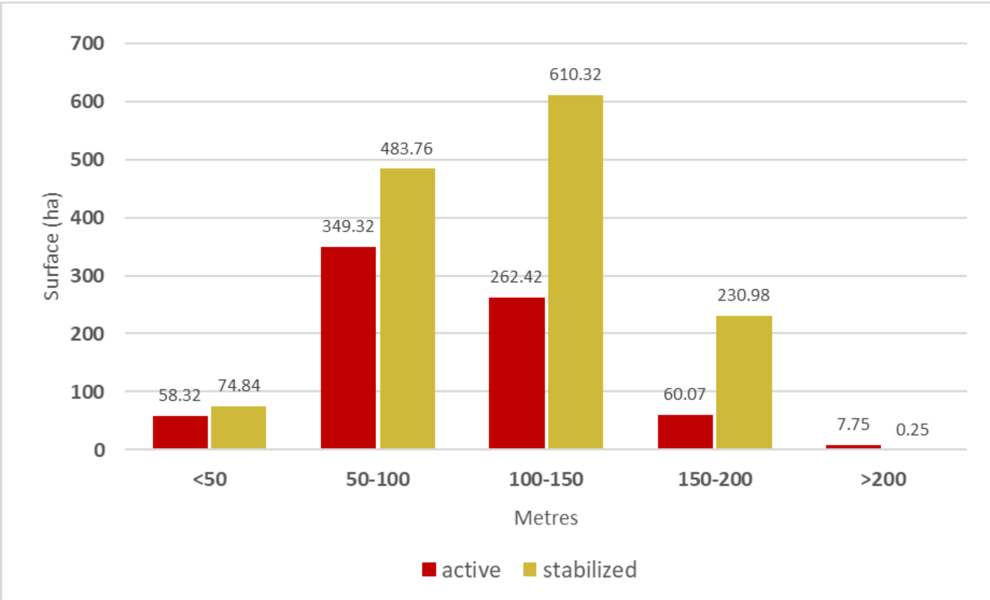

Figure 10. Surfaces occupied by each landslide type on altitudinal classes

Taking into account the relationship between landslides and hill slope on which they are distributed, we notice that most of the slides are spread on slopes ranging from 5 ° to 13 °. The 7-9º and 9-11º classes have a maximum favourability for both types of landslides and represent a total weight of 47,75% of the total area of landslides in the researched area (Figure 11).

The smallest share is occupied by the slopes up to 3º, here the share of landslides reaching 7.79% (166.51 ha), but also by the slopes range of 13-15º and by those above 15º, where the landslides represent 5.89 % (125.93 ha) and 2.38% (50.85 ha), respectively.

The frequency of landslides distribution in the plain ranges from low to medium (Mițul et.al., 2004), so the frequency of landslides varies from 1-10 landslides in 100 km² up to 10-30 landslides in 100 km². The average frequency of the landslides is about 9 landslides per 100 km².

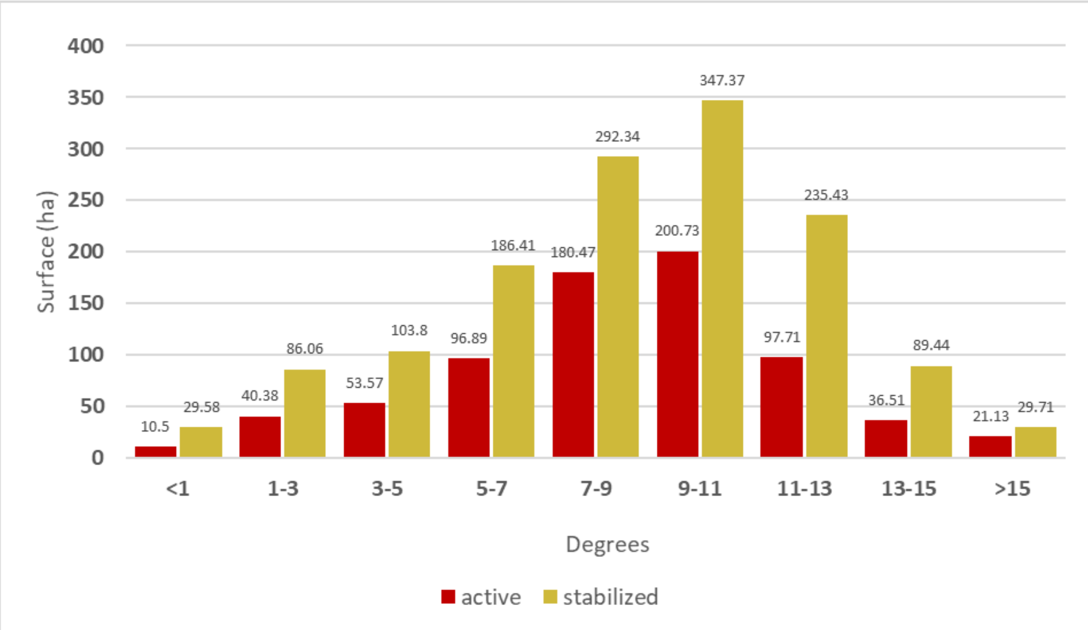

Figure 11. Surfaces occupied by each landslide type on slope classes

Conclusions

When the degree of landslide damage is considered, the Lower Bic Plain is divided into two parts, the north and the south. In the northern part, the number of landslides reaches up to 9 units per 100 km², and in the south part up to 10 units.

The spatial distribution of landslides reveals their greater predominance in the N-S direction with a rare spread to NV and SE. Many degraded areas have been set up by works carried out around 1990. However, because of anthropic activity, conditions that led to the resumption of these processes have been created

For the first time, a landslide classification was performed according to a certain criterion. Moreover, no classification was made for such a large territory.

The number of stabilized landslides is about the same as the number of active landslides, but as surface they almost double the surface of the active landslides. The minimum surface area of a landslide in the plain is 0.23 ha, and the maximum area is 117.79 ha. The average area of a landslide is 10.13 ha.

Most active landslides are concentrated in the central part of the surveyed territory, it is also observed that these landslides are concentrated at altitudes that considerably exceed the average altitude of the plain. Here it has been found that the most favourable altitudes for the development of this process are the altitudes between 100-150 m and the most favourable slope would be the surfaces with slope ranging between 9º and 11º.

Due to the fact that we know the areas affected by active landslides, we can draw more attention to these territories. Thus, when measures are required to prevent or improve the affected lands, the type of landslides will be taken into account in order to increase their efficiency.

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