CONTRIBUTIONS TO SPATIAL LANDSLIDE ASSESSMENTS IN THE BÂC TABLELAND

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ABSTRACT:

The article is dedicated to studying landslide distribution patterns and to assessing landslide development using large-scale remote sensing data and GIS technologies. There were obtained digital models of elevation and landforms within key sectors. There were shown up dependency of the process development on morphometric characteristics of the slopes. Also, there were indentified different dependency rates for the conditions within different key sectors.

1. Introduction

Landslides in the Republic of Moldova are very common. However, this process manifests more frequently in the plateau and hilly regions, first of all, in the Central Region of the Republic of Moldova, known as Codrii heights or Bâc heights.

Landslides annually cause damage to property, destroy houses, roads, industrial objects, agricultural lands etc. In the Republic of Moldova, in the period of 1970 and 2005, annual landslide area growing rate was reached up to 1000 ha; in this time period Bâc heights has the highest frequency of landslides: 40-50 landslides/100 km^2.

Present work is elaborated within the project supported by the NATO named “Landslide susceptibility assessment in Central Part of Republic of Moldova”, Science for Peace and Security Program (Award No:SfP-983287) (launched on March 25, 2009), which is being realized at the Institute of Ecology and Geography MAS within Landscape Science and Dynamic Geomorphology labs, in collaboration with Geological Engineering Department of Hacettepe University, Ankara, Turkey.

The project’s general objectives are the following:

- Elaboration of the methodology of landscape studying, using remote sensing and geoinformation technology methods;
- Landslide inventory and description;
- Landslide causes assessment;
- Elaboration of landslide susceptibility map of the Bâc heights, using various methodologies, and assessment of their performance;

- Providing information for the Project's end-user (Civil Protection and Emergency Situations) with the purpose of taking decisions and proposing recommendations on diminishing landslide impact on economy, environment and human lives.

Below, we will present short information on the particularities of spatial distribution, frequency and perimeters of landslide affected areas within Bâc heights in general, as well as within the project's key sectors.

2. Object of study and methods

Assessment works of landslide distribution depending on the morphological and morphometric features of relief have been initiated at the Institute of Geology and Seismology and Institute of Geography MAS at the beginning of 1980s (*Левадюк, 1983; Левадюк и др. 1990; Матвеева, 1985; Сыродоев и др. 1994*). The most diversified situation has been registered in Central Moldova. Therefore, based on the Project's targets, landslides in the central region of the Republic of Moldova were selected. The area is named as the Bâc heights. These heights stretch between Prut and Răut Rivers, having the northern limit more abrupt, marked by Moldavian Coast, with more mildly sloping to the south, at the contact with South-Moldavian hilly plain (*Donisă et al., 2009*).

In order to assess region's landslide susceptibility, three key sectors were selected: Nisporeni, Călăraşi and Criuleni with total surface of 1019 sq. km, situated in different geological and geomorphologic conditions, being characterized by various shares of forests and land use types.

Bâc heights' and key sectors' morphometric description, landslide area and frequency assessment have been realized using topographic maps and satellite images for some regions, as well as GIS (Geographic Information Systems). Digital elevation model (DEM) have been produced from 1: 25 000 topographical maps for the three key sectors.

The objective of this study consists in the assessment of distribution pattern of the number of landslides and of the perimeters occupied by these processes depending on morphometric characteristics of the relief.

3. Methodology

According to the particularities of relief fragmentation, certain authors (*Каманин, 1953; Взнуздаев, 1960*) include Bâc heights among mountains of erosion.

The highest altitude of the heights reaches up to 429 m (Bălăneşti Hill), mean altitude constitutes 177 m. Relief is formed on the Bessarabian and Kersonian deposits, mainly clay-sandy, but, in the eastern part, there are strong intercalations of limestone. Slopes' upper sectors and the highest interfluves are composed of alluvial and deltaic sediments of Balta and Stolniceni Series, in south-east and of Pliocene-Quaternary sands and pebbles, covered by massive loess and loess-type deposits. Relief is represented by long interfluves, with structural tablelands and relatively large valleys of the Dniester River's tributaries. In the western part, shorter Prut's tributaries have fragmented more intensively the heights, with shorter, narrower and lower interfluves. And here cuestas are presented, having western and, especially, north-western orientation.

Interfluves, sometimes even in the form of crests, are narrow, in some areas under 100 m width. In some regions interfluves can be completely affected by landslides, intensively developed on the adjacent slopes, as there is the case, for instance, of northern slopes of Măgura hill, of Cula-Ichel interfluves etc.

Within the heights energy of relief varies from 200-250 m to 250-300 m, sometimes reaching up to 320-330 m. Fragmentation density fluctuates between 1.0 and 5.13 km/sq.km, with mean value of 2.27 km/sq.km.

Clay-sand facies, high share of slopes (more than 85% of total heights' area) and morphometric particularities of relief facilitate intensification of gravitational processes, especially landslides that have a share of 33.3% of the total region's area (*Левадюк, 1983*). Within Bâc heights there are located approximately 1/3 of total landslide number and more than 40% of the total landslide susceptible area, among the latter 158 thou. ha represent territories with contemporary landslides (*Левадюк и др., 1990*). Total area of the landslide susceptible territories exceeds 240 thou. ha. The most active landslides are concentrated on the sides of 164 hirtops, identified on the heights' territory (about 46% of the total number of hirtops in the Republic of Moldova). Some hirtops' area exceeds one thousand hectares; the biggest hirtop, the one between Lozova and Huzun villages, has an area of 1210 ha and dimensions of 3.5 x 5.5 km.

Thus, Bâc heights have morphometric, geologic and hydrogeologic conditions favorable for intense development of slope processes, especially landslides.

The first key sector, Nisporeni (Fig. 1), with the area of 317.6 sq. km, is situated within the Western Bâc heights, being a part of the highest zone of this region. Relief here is presented by narrow interfluves, in some places in the form of ridge with 10-30 m width that separate a system of sub-meridional Prut tributaries' valleys, which have a strongly evidenced left asymmetry. Highest altitudes exceed 390 m; mean altitude equals 153.7 m; relief energy reaches up to 240 m. Within this key sector there were identified 101 landslides having total area of 1484.8 ha (14.85 sq. km).

In the Călăraşi key sector highest altitude reaches 385 m, mean altitude equals 195 m. this sector is characterized by significant energy of relief with the maximum figure of 310 m. About 50% of sector's territory is covered by slopes with declivity greater than 7°. These relief characteristics, in parallel with domination of clay-sand deposits, determine formation of a high number of landslides, more than 180.

Relief in the Criuleni key sector is not as high as in the previous two, being represented by late Pliocene Dniester River terraces and being fragmented by left Dniester tributaries. Altitudes, usually, do not exceed 200 m, 223 m is the highest one, mean altitude equals 112 m. Average figure of the energy of relief is just about 30 m, the maximal one 136 m. Alluvial plain relief and the specificity of geologic composition (frequency of sands, pebbles and limestone) determine weaker development of the landslides, comparing to the two previous areas.

Landslide distribution depending on slope and aspect. Slope's declivity within landslide perimeters was expressed in degrees grouped in the following classes:

0-2°, 2-5°, 5-7°, 7-10°, 10-15° and >15°

In the Nisporeni and Călăraşi key sectors the greatest share of landslides (88% and 73% accordingly) is located on the slopes with declivity between 7 and 15° that coincides, in general, with the results reported by other researchers (*Орлов, Устинова, 1969; Левадюк и др. 1978*). In the latter sector, unlike the first one, more landslides appear on the slopes of more than 15°. These landslides concentrates in the upper segments of slopes, where the declivity is higher, within numerous hirtops presented in the sector.

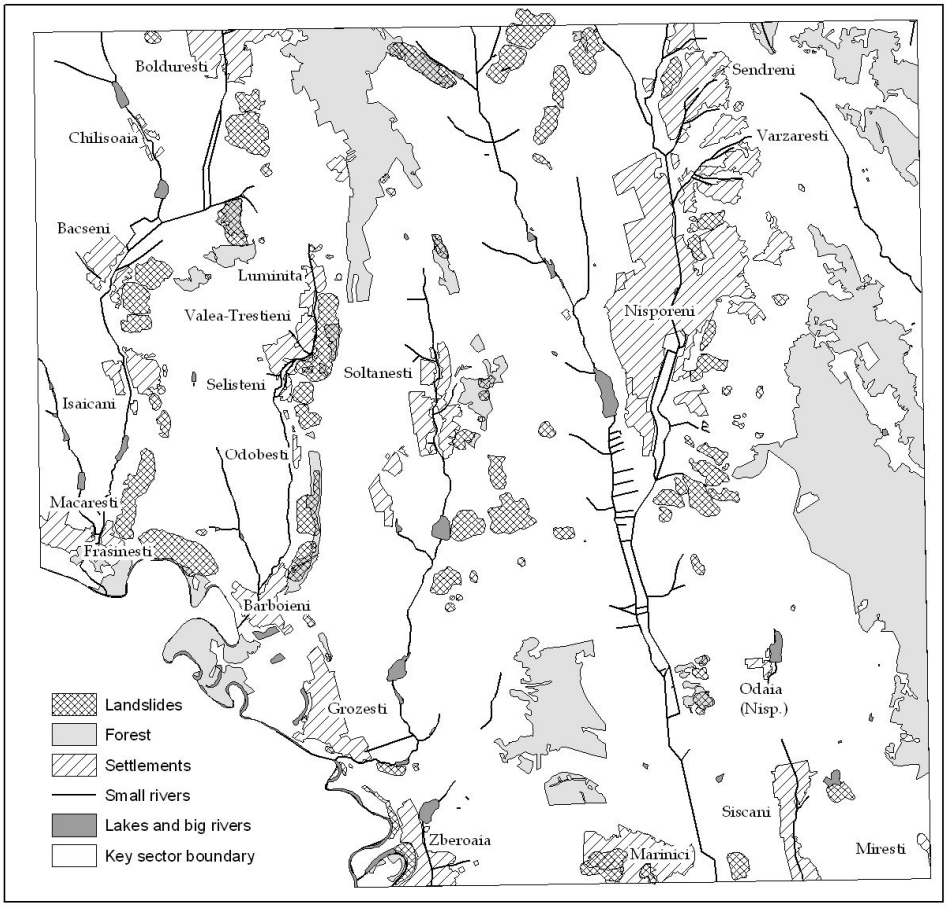


Fig. 1. Nisporeni key area overview.

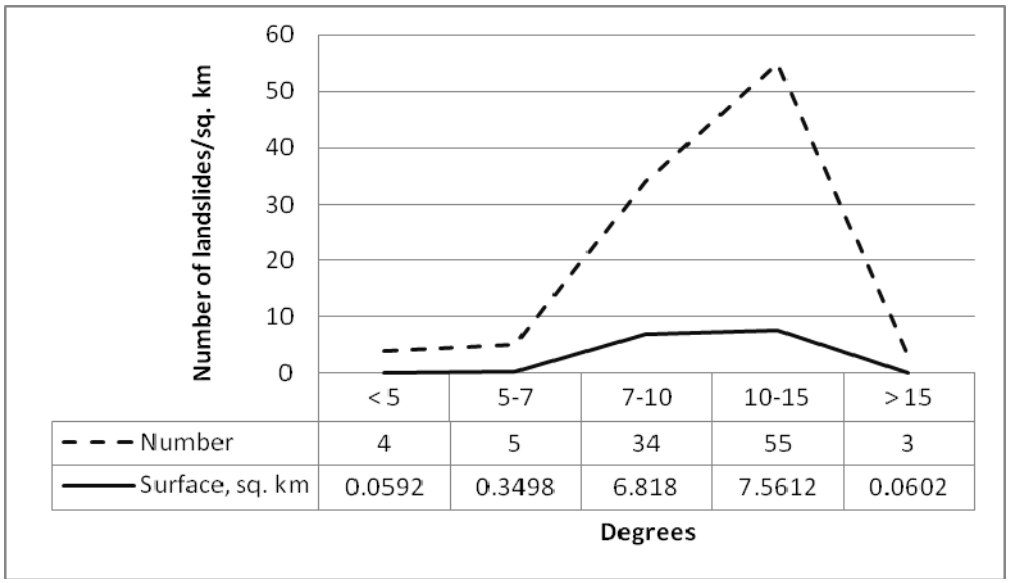
In Criuleni key sector 53% of landslides are located on the slopes with the declivity lower than 5°, and about 42% on those with the declivity of 7-10°. Small number of landslides in the declivity class of 5-7° can be explained, probably, by participation of Sarmatian (Bessarabian) limestone in slope composition of this area.

Maximal figures of perimeters occupied by landslides generally correspond to the distribution of landslides (Fig. 2).

Distribution of landslides by aspect. Landslides have been grouped into eight aspect classes (N, NE, E, SE, S, SW, W, and NW). Landslide distribution by aspect within key sectors is different. In Nisporeni key sector about 67% of the number and area of perimeters covered by landslides are located on western and south-western slopes; in the Călăraşi and Criuleni key sectors landslides are dominantly presented on the northern, north-western and north-eastern slopes. In all these cases landslides are localized on the front parts of cuestas, and one cannot speak about some climatic influences.

4. Results and Conclusions

Among morphometric characteristics of the topographic surface special role in landslide distribution is played by slope declivity and energy of relief. The most abrupt slopes within study area are characteristic to Nisporeni and Călăraşi key sectors, remarkable for the number of landslides as well.



	< 5	5-7	7-10	10-15	> 15
Number	4	5	34	55	3
Surface, sq. km	0.0592	0.3498	6.818	7.5612	0.0602

Fig. 2. Distribution of landslides in Nisporeni key sector by slope declivity.

Thus, on the basis of 1:25 000 topographic maps, in Nisporeni key sector 101 landslide areas have been inventoried, in Călăraşi area 184 landslides and in Criuleni key sector 84. Totally, there were identified 372 perimeters with landslides. These data, however, are preliminary; they are rough if compared to the information extracted from the maps at larger scales. Following the conclusions of several researchers (*Левадюк и др., 1978; Rădoane, Rădoane, 2007*) the error in determination of the area covered by landslides in our case, comparing to the figures extracted from 1:5 000 topographic maps, is about 30%. For getting reliable data regarding the number and area of the perimeters covered by landslides, it is necessary

to realize inventory, mapping and description of landslides in the field, using modern technologies (GPS) and remote sensing techniques.

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