ASSESSMENT OF LANDSLIDE DISTRIBUTION AND TERRITORIAL DYNAMICS WITHIN THE CĂLĂRAŞI KEY SECTOR USING GIS

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Resumé L'étude représente une analyse détaillée de la propagation des glissements de terrain sur un secteur clé, dans le district de Călăraşi - une zone fortement touchée par les processus de versant. L'analyse était basée sur les cartes topographiques à l'échelle 1: 25 000 (année 1970) et images orthophoto (année 2007) avec une résolution de 40 cm et les recherches sur le terrain. Avec l'utilisation du SIG on a évalué l'influence de la lithologie, les conditions géomorphologiques et l'utilisation des terres sur la dynamique temporelle et répartition spatiale des glissements de terrain. Grâce à ces techniques ont été déterminé le nombre de glissements de terrain (104) et leurs principales caractéristiques (superficie, type, l'impact sur les communautés, etc.).

Cuvinte-cheie : alunecări de teren, Podişul Codri, sectorul Călăraşi.

Introduction

Landslides occur on the entire territory of the Republic of Moldova. This process is manifesting in the hilly area more frequently though, first of all, in the central part of the Republic of Moldova, known as Codrii Heights (*Podişul Codrilor*) or Bâc's Codrii (*Codrii Bâcului*), Bâc's Codrii Massif (*Masivul Codrilor Bâcului*). At present, landslide frequency is about 40-50 landslides/100 sq.km within Bâc's Codrii. Landslides cause significant material losses every year, destroying houses, roads, industrial buildings, agricultural lands etc.

The present study is realized within the project "Landslide Susceptibility Assessment in the Central Part of the Republic of Moldova", sponsored by NATO within the Science for Peace Programme (Project no. SfP-983287, launched on March 25, 2009). The project is being realized at the Institute of Ecology and Geography within the labs of Landscape Science and Dynamic Geomorphology in collaboration with Geological Engineering Department of Hacettepe University, Ankara, Turkey. Project's general objectives are the following:

- Development of landscape research methodology, using remote sensing methods and geoinformation technologies;
- Landslide inventory and description;
- Assessment of landslide triggering factors;
- Development of the landslide susceptibility map for Codrii region, using various methods, and evaluation of its accuracy;
- Delivering the information to the final user (Civil Protection and Emergency Situations Department), with the aim of decision-making and proposing recommendations for diminishing landslide impact on economy, environment and human lives (Boboc N.,. Ercanoglu M., et al. 2009).

The object and research methods

In the current work we are analyzing territorial distribution and dynamics of landslides in the Călăraşi key sector, depending on natural conditions and land use types.

Assessment of landslide distribution can be made depending on various triggering factors. There are many classification schemas of landslide causes. U.S. Department of the Interior, U.S. Geological Survey (Lynn M. Highland, Peter Bobrowsky, 2008) groups them into three main categories:

1. Geological causes
2. Morphological causes
3. Human causes

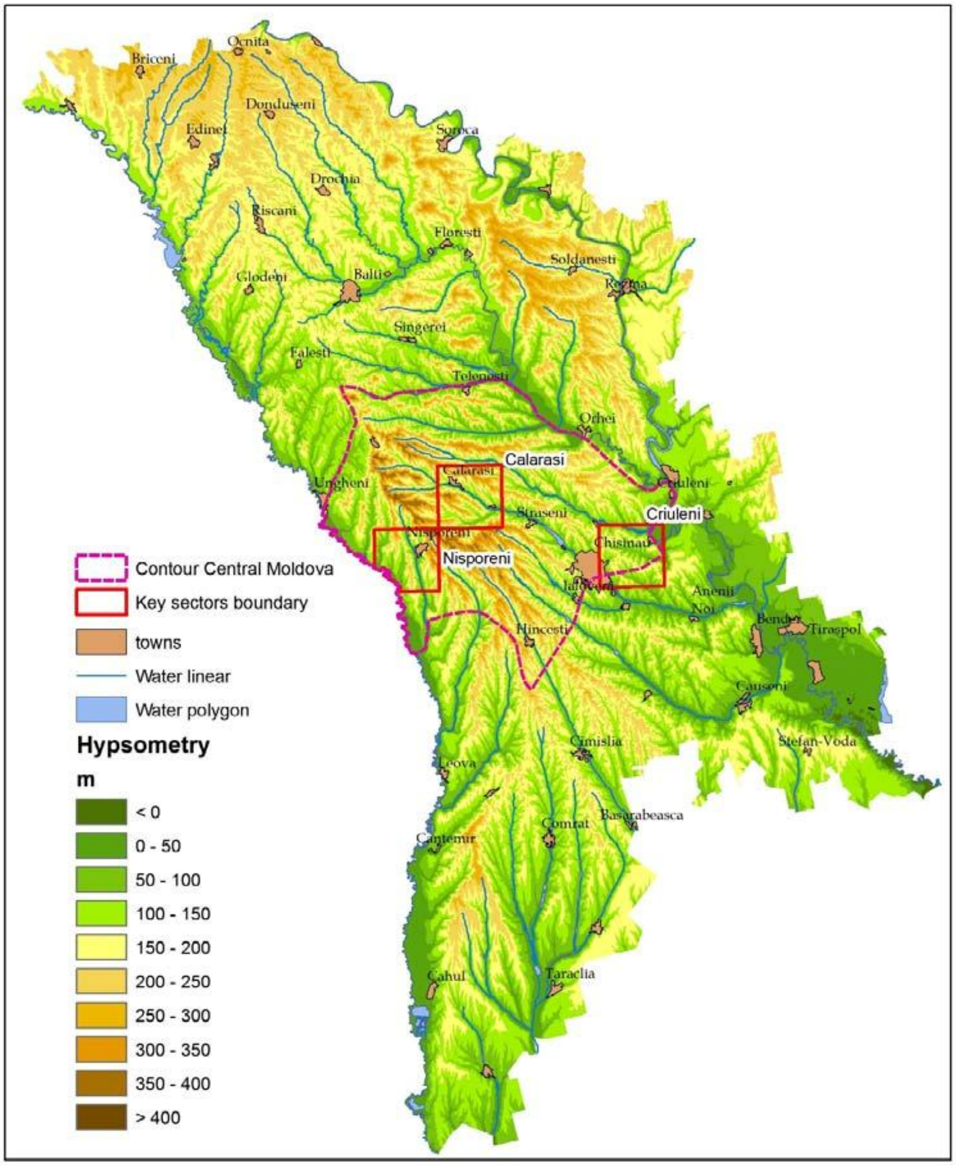


Figure 1. Study area and the key sectors

The very first assessments of landslide distribution on the Republic of Moldova's territory were made at the beginning of XXth century by O.K. Lange (1916) and T. Poruchic (1917) linking those to geological factors.

Since 1960-1970 much more works have been appearing (S. Orlov & T..Ustinova, 1969; S. Orlov & Timofeeva, 1974; E. Miţul et al., 1990; Sîrodoev Gh. et al., 2009, etc.), which examine influence of geological structure and hydrogeological peculiarities on the landslide occurrence and evolution on the entire territory of the Republic of Moldova or consider this process as a natural risk phenomenon in certain regions or administrative unitsThe very first assessments of landslide distribution on the Republic of Moldova's territory were made at the beginning of XXth century by O.K. Lange (1916) and T. Poruchic (1917) linking those to geological factors. Since 1960-1970 much more works have been appearing (S. Orlov & T. Ustinova, 1969; S. Orlov & Timofeeva, 1974; E. Miţul et al., 1990; Sîrodoev Gh. et al., 2009, etc.), which examine influence of geological structure and hydrogeological peculiarities on the landslide occurrence and evolution on the entire territory of the Republic of Moldova or consider this process as a natural risk phenomenon in certain regions or administrative units.

Analyzing any hazard, five categories of informational sources can be mentioned (Rădoane M. & Rădoane N., 2007):

1. Professional literature;
2. Existing maps;
3. Aerophotograms, orthophotoplans;
4. Field research;
5. Sampling and lab testing.

Geological features of the studied area were analyzed using 1:50000 geological maps, bibliographical sources and field research. In order to evaluate the role of disjunctive tectonic structure in landslide occurrence and dynamics geological map, landslide distribution map and tectonic faults map were analyzed together.

Morphometric features of the relief were analyzed using digital elevation model generated (DEM) as a result of digitizing topographic maps published in 1970. Slope angle and slope aspect maps were derived from this DEM. Thus, territorial distribution of landslides was analyzed in relation with these morphometric features.

Land use was assessed using topographic maps for 1970 and Landsat5 TM satellite images for 2004.

Landslide distribution analysis was realized using 1:25000 topographic maps (for 1970) and 40-cm resolution orthophotographic images for 2007; the accuracy of remotely sensed data was checked in the field.

The objective of this study consists in the assessment of landslide distribution depending on geological and geomorphologic features and land use peculiarities within the Călăraşi key sector.

Lithology and landslide frequency

Special role in the formation of contemporary relief of the Călărași key sector is played by friable Sarmatian rocks represented mainly by clays and sands (Figure 2). Sands with alluvial gravel (in southern part of the region) and younger deltaic ones dominate on the interfluves.

Floodplain bedrocks and lower segment of the slopes of Bâc River valley and its tributaries is composed of Middle Bessarabian deposits, represented by clayey rocks. Middle Bessarabian cover deposits are situated at 100 m altitude close to Bucovăţ town and about 200 m in the Călărași town area.

Middle part of the slopes is composed of sands, clays, aleurites with thin intercalations of Upper Bessarabian oolitic limestone; these strata are up to 80 m thick.

The upper part of the slopes and interfluves at the altitude 220-345 m are composed of rhythmical series of Khersonian-Meotian clayey-sandy deposits. Cross-stratified sands contain, sometimes, lenses of sandstone. In the upper part they gradually shift into fine-granulated clayey sands and aleurites. Maximal thickness of Khersonian-Meotian deposits reaches up to 120 m.

Hill ranges with elevation of 340-380 m are composed of the alluvial deposits of the lower part of Middle Kimmerian, represented by Stolniceni series (XVIth terrace) on the interfluves Recatău – Bîc, to the north of Horodişte village. Variously granulated sands and lenses of gravel and conglomerates with small buckets are 3-10 m thick (Bukatchuk et al., 1979). Compact clays and aleurites are represented by floodplain facies of up to 40 m of total thickness.

Deposits of the upper part of Middle Kimmerian, represented by *Călăraşi series* (XVth terrace), are located on the interfluves Bâc–Ichel; they are constituted of sands and gravel with inclusions of the buckets of

Carpathian jasper and silica fragments and sandstones, of 4-7 m thick, attributed to the riverbed facies (Bukatchuk et al., 1983). Floodplain facies overlays these deposits, being represented by semi-compact aleurites 2-2.5 m thick and clays of 1-1.5 m thick. In the majority of cases sands outcrop on the interfluves, where they are covered just by contemporary soils. Elevation of their surface constitutes 295-327 m.

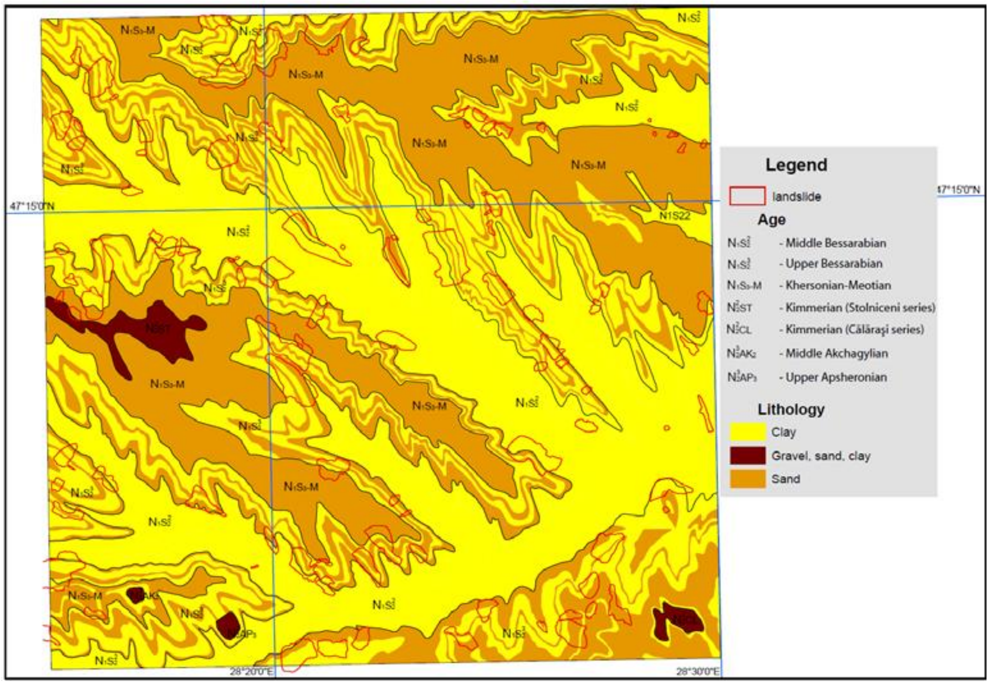


Figure 2. Geological map

Middle Akchagylian Hruşova deposits (XIth terrace) are presented on the Răcătău-Bucovăţ interfluve. They are mainly represented by a riverbed facies composed of sand strata with small granules (1-2 mm in diameter) and strata of fine-granulated sand, floodplain aleurites and sandy clays. Sand strata are about 12-15 m thick, while clays reach up to 1 m in thickness. Elevation of the base of these alluvial deposits is of 297 m.

Lithological structure has a significant influence on landslide distribution (Figure 2). Thus, 4 landslides occur in Khersonian-Meotian sands, 10 – in Middle Bessarabian clays, 2 – in Kimmerian alluvial deposits, while 88 – on the slopes composed of intercalations of Upper Bessarabian sand and clay. The great majority of the landslides (90%) occur in clays, having Middle Sarmatian or Khersonian-Meotian clays in their upper part. Translational landslides (94.2%) dominate among the modes of movement.

Relief morphometry and landslides

Bâc's Codrii are the highest relief unit in Moldova, having the highest altitude of 429 m (Bălăneşti hill) and average elevation of 177 m (Figure 1); it also has the highest relief energy varying from 200 m up to 330 m. Average slope angle is 7.5°, while the extreme values exceed 30°. Fragmentation density has significant values as well, varying between 1.0 km/sq.km and 5.1 km/sq.km, with an average of 2.3 km/sq.km.

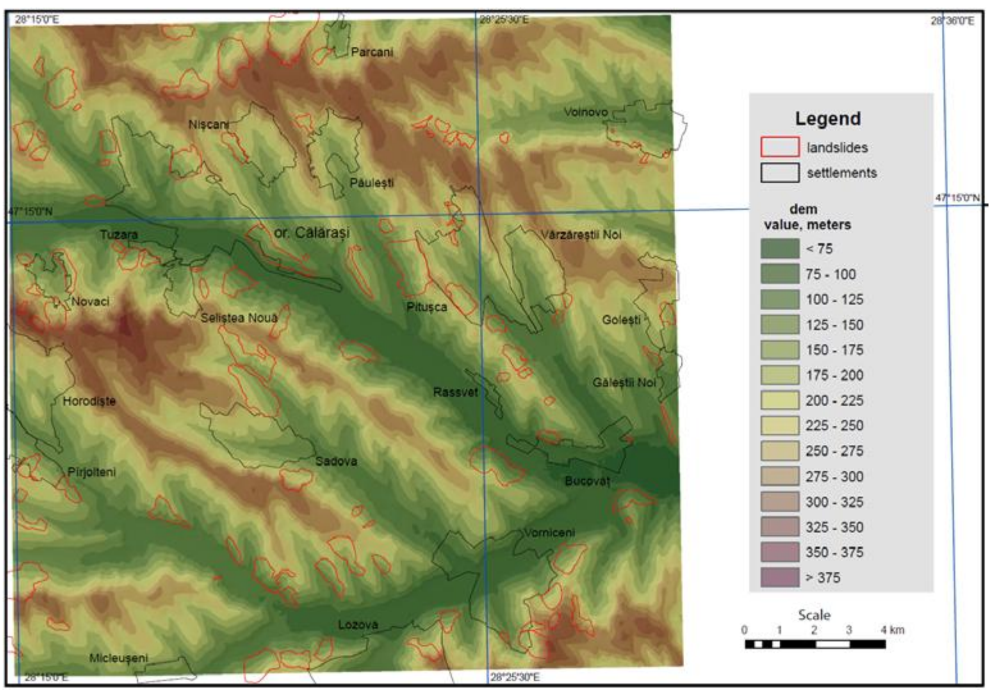


Figure 3. Landslide distribution by elevation

Elevation varies within Călăraşi key sector from 67 m (in the Bâc River floodplain) up to 384.1 m (Seliştea Nouă hill) (Figure 3). Average elevation constitutes 195 m. About 2/3 of the sector's surface is situated between 100 m and 250 m. The great majority of landslides (89 from 104) are situated between these elevation levels as well (Figure 4): mainly, landslides are located within the range 150-200 m (36 landslides); 8 landslides are located at the altitudes higher than 250 m, and 2 of them are situated below 100 m.

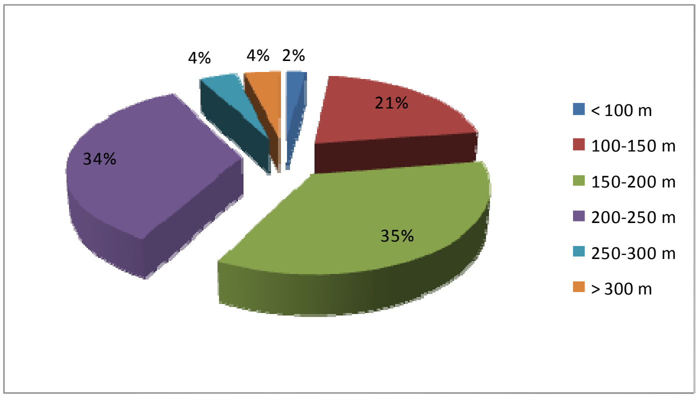


Figure 4. Landslide distribution by elevation levels

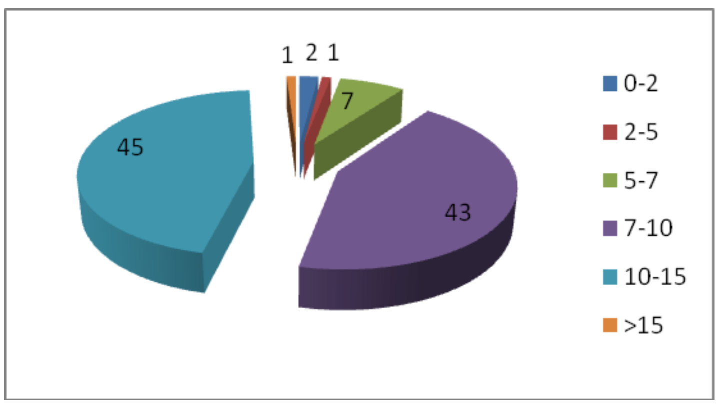
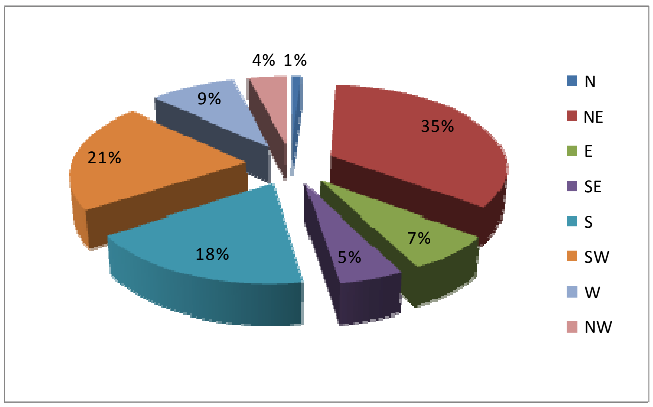


Figure 5. Landslide distribution by slope angles

Slope angle in the sector varies within large limits. Average slope angle constitutes 7.5°, while the extreme values reach up to 32.2° (to the north of Nişcani village). The highest landslide frequency (90%) was observed on the slopes with angles varying between 7° and 15° (Figure 5).

South-western (19.1%), north-eastern (17.4%), eastern (14.1) and southern (14%) slopes dominate the sector. North-eastern slopes are more susceptible to landslides: here 35% of all landslides are situated. A high landslide frequency was observed on south-western (21%) and southern (18%) slopes (Figure 6).



Land use

Orthophotographic images served for the analysis of the actual structure of the land fund and landslide distribution by different land categories. In 2004, more than 2/3 of the sector's area was represented by anthropogenized and anthropic lands. Natural and semi-natural categories of lands (pastures, waters and forests) represent 31.3% (Figure 7**).**

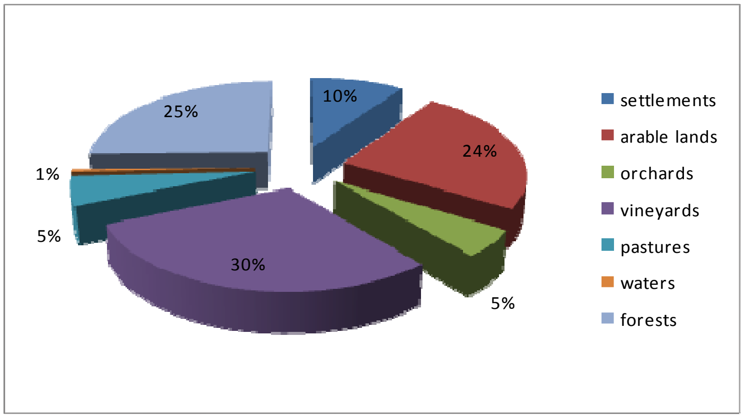


Figure 7. Land use in Călăraşi key sector

Among all the land use types perennial plantings occupy the first place embracing more than 1/3 of all landslides (Figure 8). The big number of landslides on these land use types is explained by both morphometric characteristics (high slope angles) and deep plowing. Many landslides (24%) occur on arable lands; the fact that does not contribute to their stabilization.

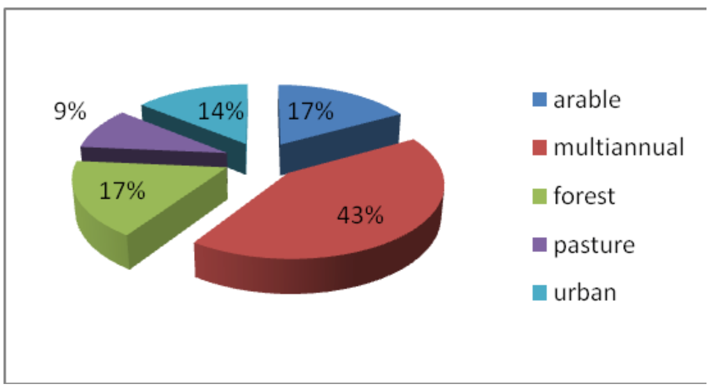


Figure 8. Landslide distribution by land use types

The same number of landslides is observed on forested lands, which were forested in 1970-1980s, being eliminated from agricultural circuit. Landslides, on which various buildings are situated, are the most dangerous. There were identified 10 such landslides: 3 in Voinovo village, 1 in Pituşca village, 2 in Călăraşi town, 1 in Vorniceni village, 1 in Lozova village and 2 in Novaci village. These landslides can cause significant material losses, and even casualties.

Land use change and landslide distribution.

As a result of analysis of 1:25000 topographic maps for 1970, in Călăraşi key sector 185 landslides were identified. Their total area constituted 3.4 sq.km or about 1% of the sector's total area. After analyzing orthophotographic images from 2007, there were identified just 104 landslides, having the total area of 25.5 sq.km, or 7.3% of the sector's area. The obtained difference can be explained mainly by the quality and precision of the used cartographic materials.

Land use change was analyzed using the same sources (Figure 10). Important changes, frequently qualitative, took place in land use between 1970 and 2004 (Figures 11 and 12): forest areas have extended by 9.3%, while arable lands and pastures have diminished by 10.7%, orchards – by 5.5%. Among the negative changes, which would have influenced landslide activation, one can mention extending of settlement territories from 5.3% to 9.6% and vineyards from 16% to 25.3%. The area covered by perennial plantings still remains relatively large; it concentrates the highest number of landslides (45) as well.

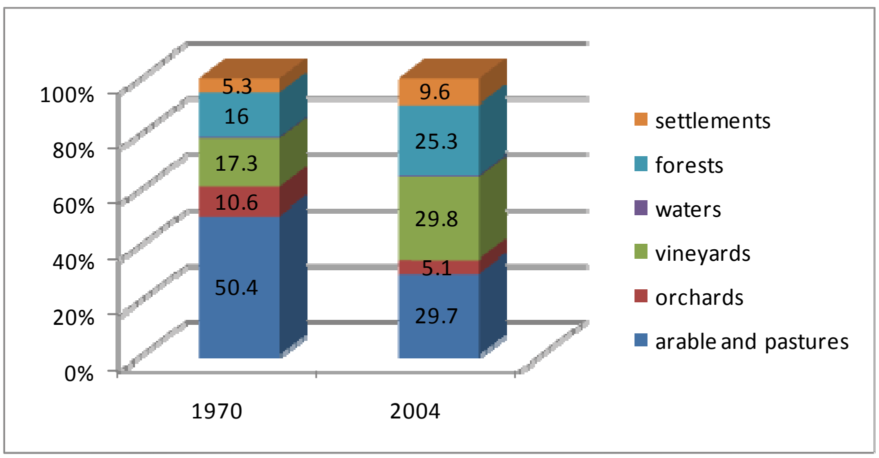


Figure 9. Land use change between 1970 and 2004

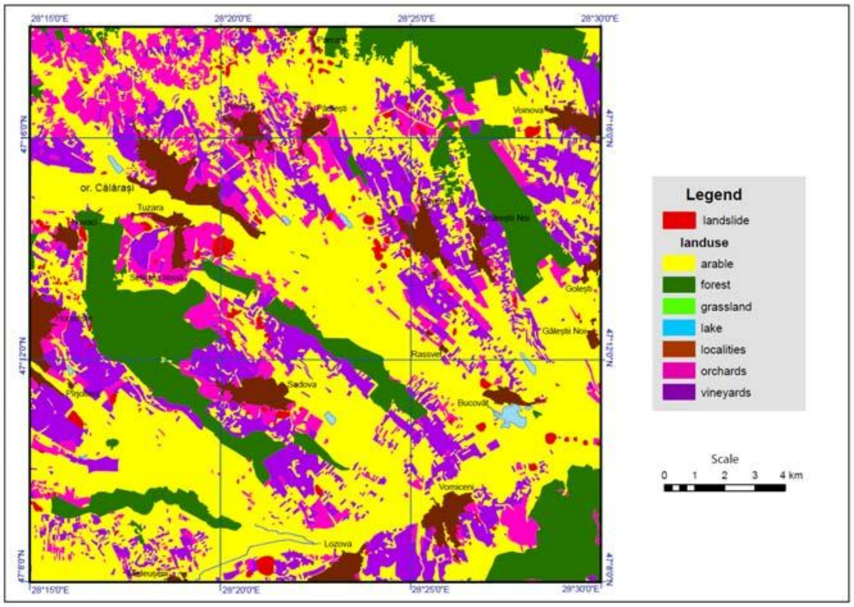


Figure 10. Land use in 1970 (after 1:25000 topographic map, 1970)

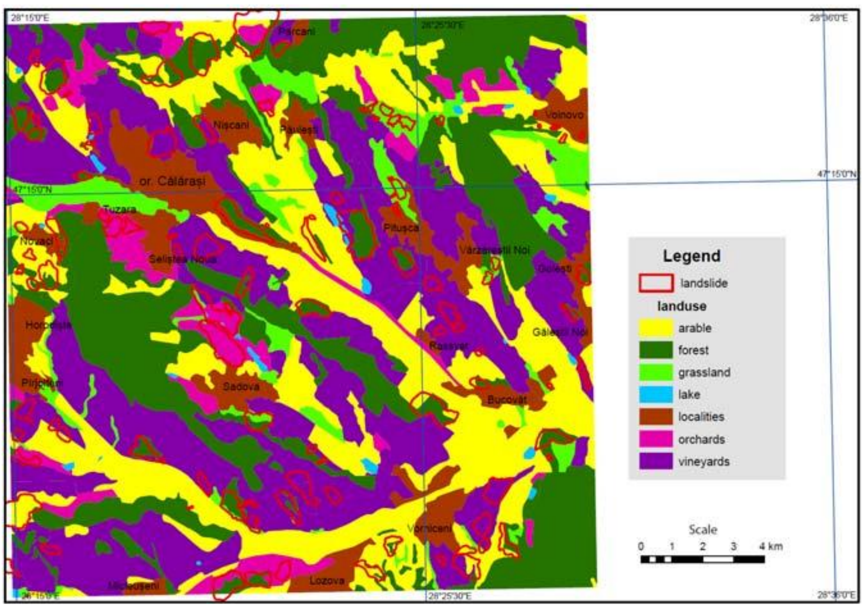


Figure 11. Land use in 2004 (after Landsat5 TM, 2004)

Conclusions

Totally, 104 landslides were identified within Călărași key sector. The great majority of them are attributed to the slope sectors, composed of Bessarabian rocks. The landslides located in the upper parts of the slopes are the biggest (about 23 ha); translational landslides dominate among all the modes of movements.

From the viewpoint of morphometric features the great majority of the landslides (89 of 104) are located within the elevation range of 100-250 m: altitudes 150-200 m are characterized by the highest value of landslides (36). North-eastern and south-western slopes have the highest share of landslides, 35% and 21% respectively.

Perennial plantings dominate, with 45 landslides, other land use types. High figure on this particular type is explained by both morphometric characteristics (high slope angles) and by deep plowing. Many landslides (18) were observed within arable lands, the fact that does not contribute to their stabilization. Landslides with buildings on them are particularly dangerous; 10 such landslides have been identified within the sector. These landslides can cause significant material losses, and even casualties.

References:

1. Arapov A.A., Gol'denberg I.M., Ivanov V.I. i dr. *Otchet o rezul'tatakh kompleksnoy geologo-gidrogeologicheskoy s'yomki territorii lista L-35-V (Floreshty), provedennoy v 1963-1964* gg. Kishinev, 1965. Mold. TGF
2. Boboc N.,. Ercanoglu M, Sîrodoev Gh., Bejan Iu., Sîrodoev I.G., Castraveţ T., Jechiu R., Muntean Valentina, Bolfos N., Serbina Svetlana *Contributions to spatial landslide assessments in the Bâc Tableland*, Analele Universităţii „Ştefan Cel Mare" Suceava, Secţiunea Geografie ANUL XVIII - 2009, 19-24 p.
3. Bondarenko L.K., Kolotova V.A., Baklanov M.K. i dr. *Otchet po inzhenerno-geologicheskoy s'yomke masshtaba 1:50 000 dlya tseley prognoza geodinamicheskikh protsessov v Teleneshtskom i Kalarashskom rayonakh Moldavskoy SSR.* Kishinev, 1983. Mold. TGF
4. Bukatchuk P.D., Burdenko B.V. *Nekotorye osobennosti stroeniya allyuvial'nykh otlozheniy pliotsenovykh terras nizhnego Pridnestrov'ya.* Geografia i khozyaystvo Moldavii. Vyp. 1. Kishinev, «Shtiintsa», 1970. C. 143-150.

5. Bukatchuk P.D., Gozhik P.F., Bilinkis G.M. *O korrelyatsii allyuvial`nykh otlozheniy Dnestra, Pruta i Nizhnego Dunaya.* Geologia chetvertichnykh otlozheniy Moldavii. Kishinev, «Shtiintsa», 1983. C. 35-64.
6. Bukatchuk P.D., Konev Ju.M., Pokatilov V.P. i dr. *O raschlenenii porod srednego sarmata k zapadu ot Kishinevsko-Kamenskoy rifovoy gryady.* Geologicheskaya structura i relief Moldavii. Kishinev, «Shtiintsa», 1979. S. 34-48.
7. Bukatchuk P.D., Negadaev-Nikonov K.N. *Novye dannye o drevneyshikh allyuvial'nykh otlozheniyakh v mezhdurezh'ye Pruta, Dnestra i Yu. Buga.* Paleontologia, geologia I poleznye iskopaemye Moldavii. Vyp. 2. Kishinev, RIO AN MSSR, 1967
8. Bukatchuk P.D., Pokatilov V.P., Antipovich V.B. i dr. *Otchet o rezul'tatakh kompleksnoy gidrogeologicheskoy i inzhenerno-geologicheskoy s'yomkakh masshtaba 1:200 000 lista L-35-V.* Kishinev, 1975. Mold. TGF
9. Landsat, imagini satelitare pentru Republica Moldova, anul 2004, http://glovis.usgs.gov/
10. Lange O.K. *Neskol'ko slov o Bessarabskikh opolznyakh.* Bessarabskoe sel'skoe khozyaystvo, 1916, N 17
11. Lynn M. Highland, Peter Bobrowsky, *The Landslide Handbook – A Guide to Understanding Landslide*. U.S. Department of the Interior U.S. Geological Survey, Reston, Virginia, 2008, 147 p.
12. Mitsul E.Z., Syrodoev G.N., Kapchelya A.M., Chernov G.N. *Prirodnye faktory, predraspolagayuschie territoriyu Moldavii k proyavleniyu opolznevogo protsessa.* Levadnyuk A.T. (red.). *Opolzneopasnye territorii Moldavii i ikh ratsional'noe ispol'zovanie*. Kishinev, Shtiintsa, 1990. S. 20-37
13. Orlov S.S., Timofeeva T.A. *Geodinamicheskie protsessy v Moldavii i bor'ba s nimi.* Kishinev, Shtiintsa, 1974. 71 s.
14. Orlov S.S., Ustinova T. I. *Opolzni Moldavii.* Chişinău, Cartea Moldovenească, 1969, 158 p.
15. Ortofoto imagini pentru sectorul-cheie Călăraşi, 2007
16. Poruchik F.S. *Zametki po voprosu ob orografii Bessarabii i podrazdeleniy posledney na fiziko-geograficheskie oblasti*. Trudy

Bessarabskogo obschestva estestvoispytateley i lyubiteley estestvoznaniya. T. 6 (1914-1916). Kishinev, 1917. S. 87-117
17. Rădoane M., Rădoane N., *Geomorfologia aplicată*. Editura Universităţii Suceava, 2007, 377 pag.
18. Sîrodoev G.N., Miţul E.Z., Ignatiev L.I., Gherasi A.S. Evaluarea riscurilor de apariţie a proceselor geomorfologice periculoase. În: Constantinov T.S. (red.). *Republica Moldova. Hazardurile naturale regionale*. Chişinău, 2009. P. 8-57.
19. Topograficheskie karty Moldavskoy SSR, masshtab 1:25000. Glavnoe upravlenie geodezii i kartografii SSSR, Moskva, 1970