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RELAȚIONAREA PROCESELOR GEOMORFOLOGICE DE RISC LA UTILIZAREA TERENURILOR ÎN BAZINUL HIDROGRAFIC CUBOLTA (REPUBLICA MOLDOVA)

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Scopul articolului este de a evidenția cele mai afectate categorii de utilizare din cadrul teritoriului și care sunt procesele cele mai răspândite în aceste categorii. Pentru a face calculele necesare și pentru a reprezenta grafic rezultatele așteptate, am efectuat studiul într-un bazin hidrografic din zona de nord a țării. Este bazinul raului Cubolta, afluent al Rautului. Cu ajutorul hărților tematice a fost reprezentată fiecare categorie de utilizare a terenului și au fost prezentate datele statistice despre fiecare categorie. Ținând cont de faptul că utilizarea terenurilor este unul dintre factorii importanți care sunt luați în considerare la investigarea degradării terenurilor prin riscul proceselor geomorfologice, s-a încercat să evidențieze relația dintre procesele geomorfologice și utilizarea terenului. Datorită utilităţii funcţiilor de calcul ale software-ului Arc GIS a fost posibilă reprezentarea grafică a relației dintre procesele evidenţiate şi categoriile de utilizare a terenului din teritoriul cercetat.

Cuvinte-cheie*: alunecări de teren, ravene, eroziunea de suprafață, procese geomorfologice, utilizarea terenurilor, categorii de utilizare.*

RELATING GEOMORPHOLOGICAL PROCESSES TO LAND USE IN CUBOLTA RIVER BASIN (REPUBLIC OF MOLDOVA)

The purpose of the article is to highlight the most affected categories of use within the territory and which are the most widespread processes in these categories. In order to make the necessary calculations and to graphically represent the expected results, we carried out the study in a hydrographic basin in the northern part of the country. It is the basin of the Cubolta river, a tributary of the Raut. With the help of thematic maps, each category of land use was represented and the statistical data about each category was presented. Taking into consideration the fact that land use is one of the important factors that are taken into account when investigating land degradation through geomorphological processes risk, an attempt was made to highlight the relationship between geomorphological processes and land use. Thanks to the usefulness of the calculation functions of the Arc GIS software, it was possible to represent the relationship between the highlighted processes and the categories of land use in the researched territory graphically.

Keywords: *landslides, ravines, surface erosion, geomorphological processes, land use, landuse categories.*

Introduction

Depending on habitat, use of natural resources and spatial organization, the activation of geomorphological processes is a criterion of geomorphological risk that can cause damage or loss (economic and social). However, the degree of risk differs depending on the morphological and morphometric features, territorial distribution and association with various natural and socio-economic components of the natural environment in our case the land use [1].

Landslides' negative consequences come in many varieties, from degradation of sloping lands occupied by natural meadows and / or shrubs to partial or sometimes complete destruction of settlements or infrastructure. For example, landslide-damaged road can cause closures, forcing vehicles to take alternate routes for weeks to months. The majority of rainfall-induced landslides are shallow (less than a few meters deep), small, and move rapidly. Many rainfall-induced landslides transform into debris flows (fast-moving slurries of water, soil, and rock) as they travel down steep slopes. In addition, landslides can have cascading consequences; for example, a landslide can form a debris dam that blocks a stream channel, forming a pond. The rising pond water can eventually breach the debris dam, which can lead to downstream flooding.

Deformed Landforms are the result of the geomorphological processes that shape the landscape. Such a landscape with dynamic disturbances reduces the utilitarian qualities of the natural environment components (especially the relief, soil cover and vegetation), depreciates their aesthetic features, and reduces the possibilities of land use [2]. Erosion control and slope stabilization include measures aimed at Forest and Landscape Restoration (FLR), which is considered worldwide as a powerful approach to recover ecological functionality and to improve human well-being in degraded and deforested landscapes. In addition, rural restructuring is one of effective practices of regional planning governance for geomorphologic processes stabilization, carried out either within administrative units (communes, villages, cities) or natural units (in particular river basins of various order).

The current land use was carried out according to the Land Registry of the Republic of Moldova [3]. Taking into account the needs and goals of the research for the Cubolta River basin, the categories of land use were adapted according to the importance and relevance of certain criteria [4, 5].

There are seven different designations of land use within the Cubolta River basin: arable land, multiannual plantings (vineyards and orchards), pastures, forests and protective forest belts, water lands, marshes, infrastructure (land with buildings, localities (intra-urban land), Industrial constructions).

This article delves into the ten main types of land use, providing insights into each category's unique geomorphological processes and challenges.

Study area

The Cubolta River is one of the longest rivers in Republic of Moldova. Its length exceeds 100 km. It is a left tributary of the Raut River, the largest watercourse, which's basin is completely located within Moldova.

Cubolta River flows in the northern part of the country (Figure 1) and belongs to one of the seven medium river basins. Right-hand asymmetry should be observed in the section: the length of the right and left slopes is on average 15 and 3 km in its northern part, respectively, in the middle part, 8 and 6 km, and in the lower part, 3 and 6 km [6]. The depth of the basin reaches 115 m, and its area is 943 km². There are eight small rivers with a length of 10 to 16 km in Cubolta River basin. Seven of them are right tributaries and only one (r. Popesti) is on the left side. In total, 184 different watercourses were identified within the study area, the total length of which is 542 km; the indicator of the density of the drainage network is 0.58 km/km². The river's flow is highly regulated. By the beginning of the 1980s, more than 220 ponds were built in the basin, mostly small, from 0.001 to 0.615 km².

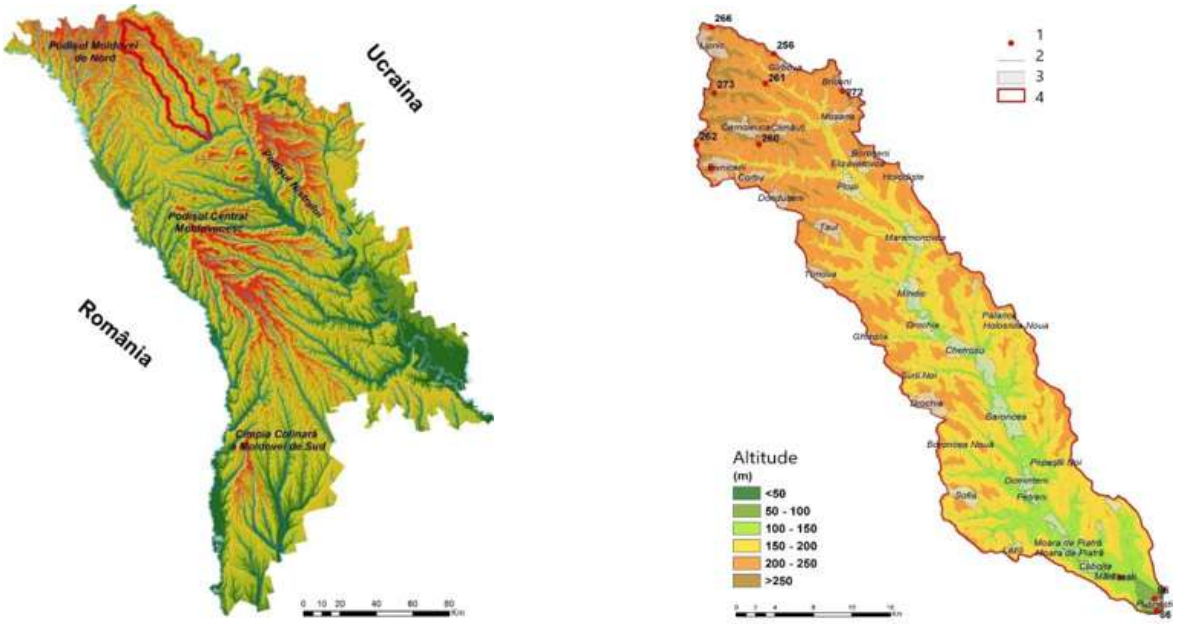


Figure 1. Location of the Cubolta River basin within the Republic of Moldova (1 - altitude; 2 - rivers; 3 - localities; 4 - river basin boundaries)

The Cubolta River basin is framed in two geomorphological units: the Northern Moldavian Plateau and the Cubolta Plain. Thus, the geomorphological characteristic of the basin corresponds to the geomorphology of these two units [7].

The relief of the Cubolta River basin is characterized by altitudes between 85-280 m, with an average altitude of 221 m. The maximum values of the altitude are 280 m, and the minimum 85 m. The highest altitudes that exceed 250 meters are recorded in the upper part of the basin. Altitudes below 100 m are present even in the lower meadow of the Cubolta River basin. According to the hypsometric map, the altitudes are decreasing from the upper part of the basin to the lower part, without registering altitudinal anomalies.

Materials and Methods

One of the objectives of this study is to classify land use and land cover status and to identify land use categories in the study area using orthophoto plans with a resolution of 0.5 m (2016, 2021 edition). Most of the orthophoto plans available on the geoportal.md (website of Agency for Geodesy, Cartography and Cadaster of the Republic of Moldova, 2024) [8] are in the public domain. In addition, many work trips were organized for getting measures in the field using the GPS device to validate the data obtained from the decoding of the orthophoto plans (Figure 2).

Using GIS technologies, we had the opportunity to represent the thematic maps related to the current land use within the Cubolta River basin and perform statistical analysis with the help of the data from the attribute table of the created vector layer [9].

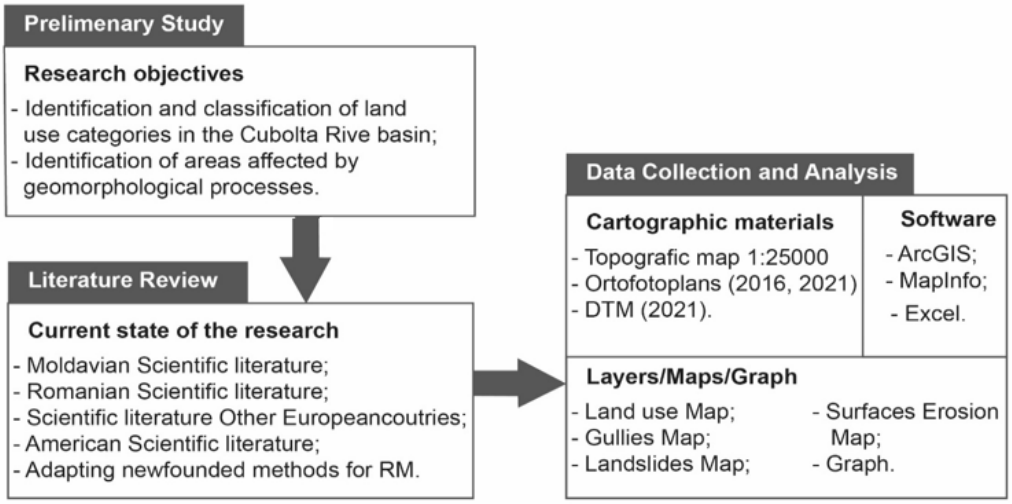


Figure 2. Research Methodology Phases

The graphical representation of the relationship between the geomorphological processes and the categories of land use was made with the help of Excel.

Results and discussions

According to land use criteria, all land use categories within the Cubolta River basin were divided into two groups: agricultural land and non-agricultural land. Agricultural land occupies the largest territory of the total study area, namely 81.96% (77291.12 ha), and non-agricultural land occupies 18.04% (17008.88 ha) (Table 1).

Table 1. Categories and subcategories of land use in Cubolta River basin (2016)

Categories and subcategories	Area (ha)	% from total area
Arable	60525,82	64,18
Multiannual plantings	3605,86	3,82
Pastures and hayfields	13159,45	13,95
TOTAL AGRICULTURAL LAND	77291,12	81,96

Forest	4130,94	4,38
Protection forest belts	1248,58	1,32
Marshes	111,41	0,12
Waterlands	963,11	1,02
Lands with buildings	9449,95	10,02
Localities	8483,54	9,00
Industrial constructions	966,41	1,02
Other	1104,88	1,17
TOTAL NON-AGRICULTURAL LAND	17008,88	18,04
TOTAL BASIN	94300	100

The arable land occupies more than half of the total territory. Vineyards and orchards – 64.18% (60525.82 ha) (Figure 3). The pastures and hayfields occupy 13.95% (13159.45 ha), being spread around the watercourses and on the slopes in immediate vicinity of them (Figure 4).

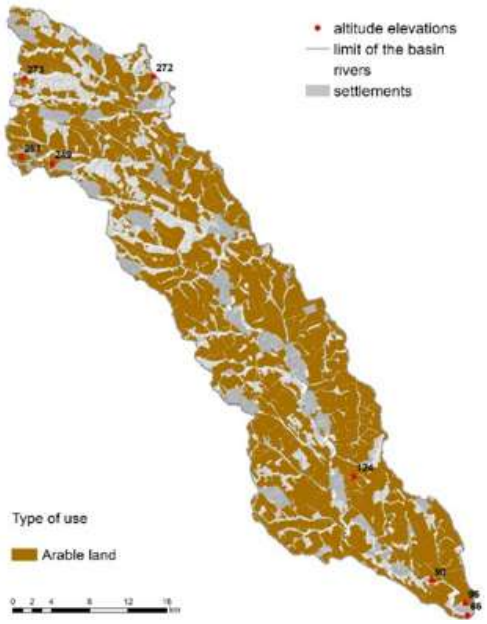


Figure 3. Arable land

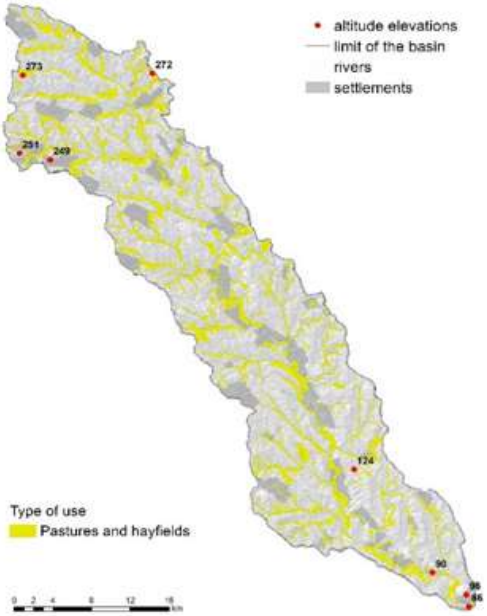


Figure 4. Pastures and hayfields

An important thing in the analysis of land damage by geomorphological processes is the fact that this subcategory of land use, practically always, is associated with landslides. Perennial plantations, especially vineyards, are spread mainly on the southeast oriented slopes on the upper course of the Cubolta River (Figure 5).

Vineyards and orchards occupy an area of 3605.86 ha, which represents a share of 3,82% of the total area of the basin. Good parts of them are in a deplorable condition for several reasons. Not less important reason is the range of terrestrial geomorphological processes.

The category of non-agricultural lands includes forest – 4130.94 ha (4.38%); protection forest belts – 1248.58 ha (1,32%) (Figure 6); water–963.11 ha (1.02%) (Figure 7); settlements – 9449.95 ha (10.02%) (Figure 8); of which industrial constructions occupy only 966.41 ha. It should be mentioned that the roads were not vectorized in polygon format. This is the reason why the data on the surfaces occupied by roads is not presented.

Most of the anthropogenic and natural deciduous forests (oak, ash, maple, acacia) are extended in the upper part of the Cubolta River basin and are practically absent in the lower course of the river. There are a lot of green forest plots on the map (Figure 6), but in most cases, they do not exceed an area of 1 ha.

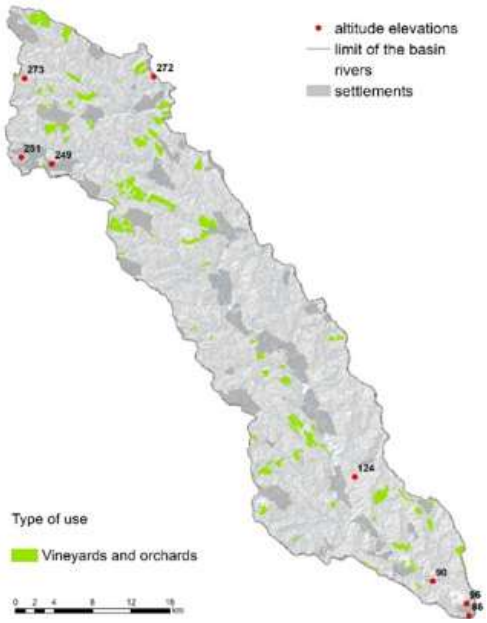


Figure 5. Vineyards and orchards

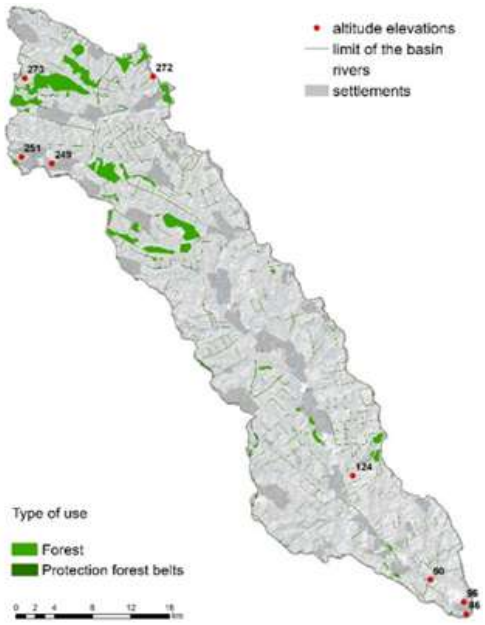


Figure 6. Forest and protection forest belts

Lands with buildings slightly exceed 10% of the total area of the basin. Of these, 1.02% are industrial constructions, mostly abandoned. Settlements represent the buildings and courtyards themselves, along with all infrastructure and gardens attached to the courtyards.

Water lands are represented by lakes, ponds and reservoirs, occupy the area of 963.11 ha (1.02% of the total study area) and are represented mostly in the middle part of basin. Near the villages Chetrosu and Gribova there are large lakes 18-85 meters long, 11-40 meters wide and 0.6-0.8 meters deep, with abundant vegetation of reeds. Downstream from the Maramonovca village, the Cubolta River crosses a series of ponds with a length of 1.2-2.8 km and a maximum width at dams of 60-300 m, depth - 1.5-5.0 m.

Marshes occupy a share of only 0.12% of the total area of the basin (Figure 7). Marshland with reed beds and sedges, sometimes shrubs are represented mostly in the middle and in the lowest part on Cubolta River basin.

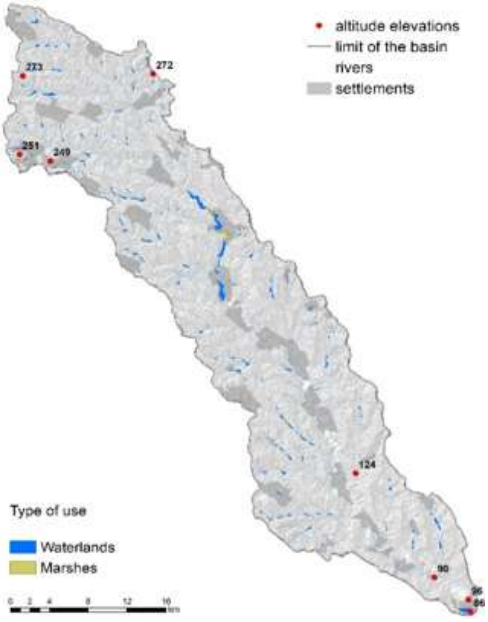


Figure 7. Water lands and marshes

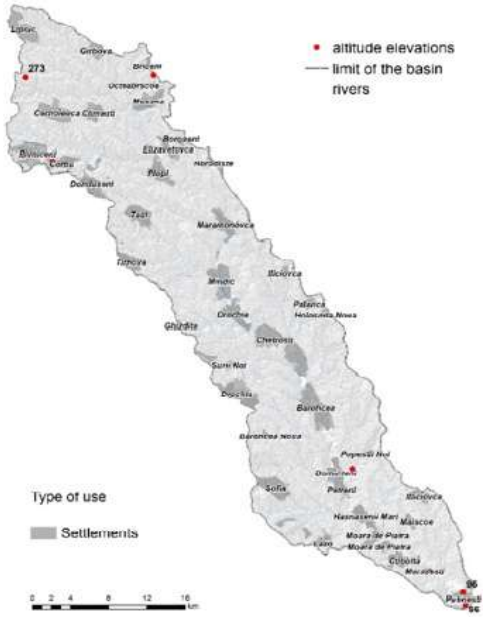


Figure 8. Settlements

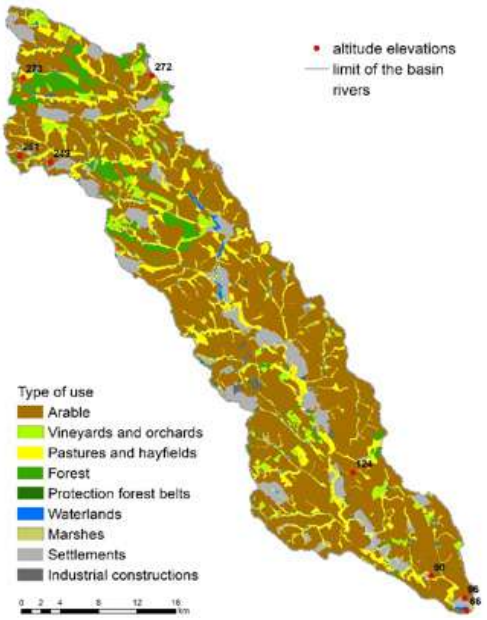


Figure 9. Land use map

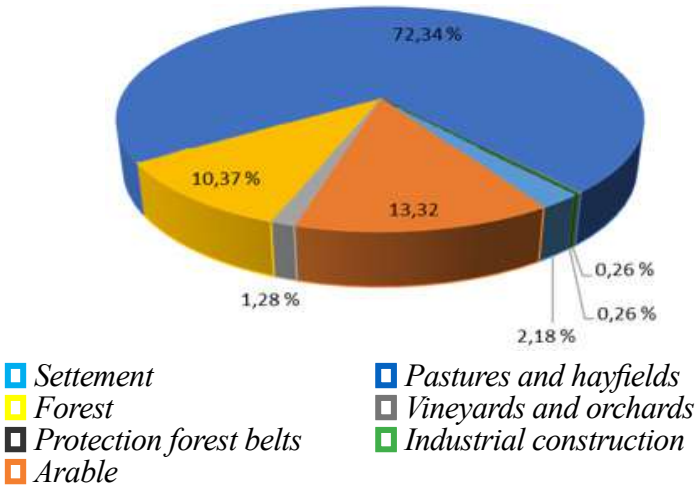


Figure 10. Share of landslides by land use category

Starting from the fact that throughout the territory of the basin, geomorphological processes are spread everywhere, an attempt was made to highlight the most affected categories of land use within the study area and which of them are the most widespread.

Landslides will be discussed at greater length in the next part of paper. [10]. Landslides are caused by rain, earthquakes, or other factors that make the slope unstable. According to the land use map (Figure 9), about 2/3 (64.18%) of the territory of the study area is occupied by arable land (Table 1), about 14% belong to the pastures and hayfields. Settlements and industrial constructions belong to 10.02% of the territory. With an area of 5.7% are represented forest and protective forest belts.

The following figures (Figure 10, Figure 11) show that a little over 70 % of the total landslides are recorded on pastures and hayfields. The area covered by forests (10.37%) and arable land (13.32%) are presented with an approximately equal weight. The system assigned around 4% of the total landslides to the other categories of land use. There, the assignment of the areas affected by landslides was carried out according to the occupational criterion of each category of land use, namely the area corresponding to each field.

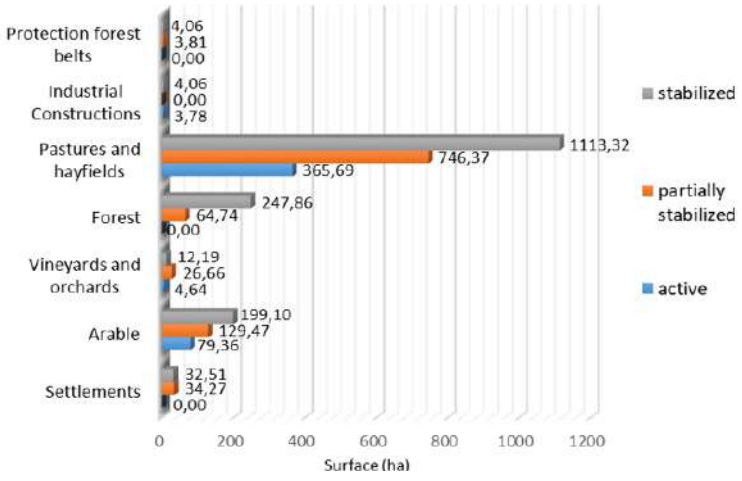


Figure 11. Surfaces affected by landslides by land use categories

A more relevant result regarding which areas of land use are most affected by the landslide process will give us the calculation of the ratio between the areas of the Cubolta River basin by categories of use (Figure 11).

If we view the map in "chart" mode, we see that pastures and hayfields remain the most affected even though they occupy an area of no more than 14%. According to the calculated percentage ratio (Figure 12), about 16.88% (≈1/5) of the total area of this use category is affected by landslides.

The next category of land use according to the ratio is presented by forests with 7.71% (about 1/10) of the total area being affected by landslides (this process did not develop in forests itself, but there are areas, which probably passed from another category of use presenting a severe degradation process).

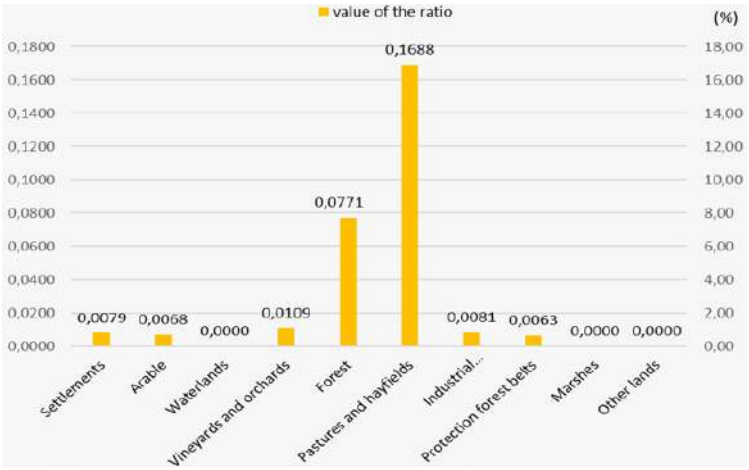


Figure 12. Correlation between land use and landslides

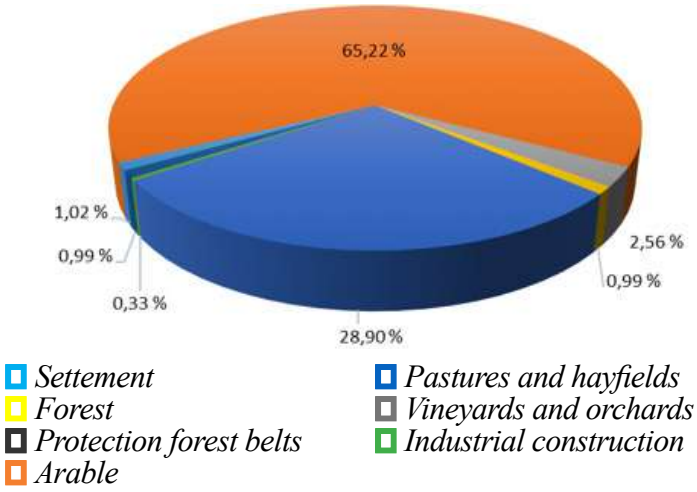


Figure 13. Share of the erosion process by land use category

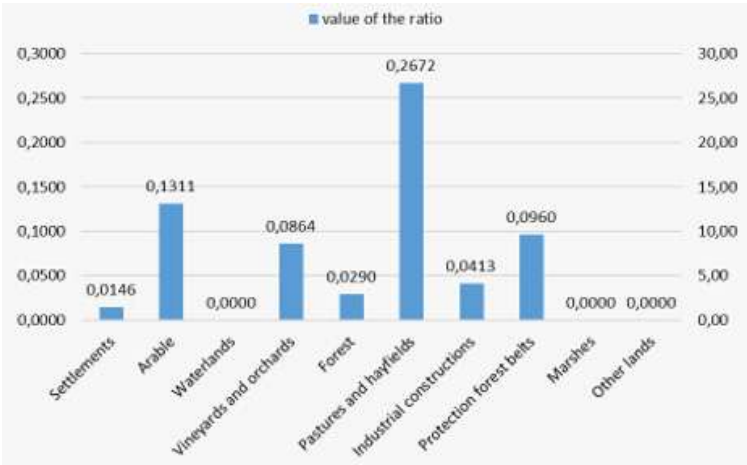


Figure 14. Correlation between land use and surface erosion

Arable land presents a percentage ratio of only 0.68% of the area, although according to the first criterion, about 13% (Figure 10) of the total landslides is located on this type of land use. Vineyards and orchards represent a ratio of 0.0109, which means that about 1.09% of this land use category is affected by landslides. The other categories of land use show a low ratio and do not reach even 1% of land affected by landslides.

The second geomorphological process considered is *surface erosion*. According to Figure 13, over 65% of the eroded surfaces belong to arable land, 28.90% of the erosion process is located on pastures and hayfields. With a weight of 2.56% are characterized vineyards and orchards, followed by settlements with 1.02% of the total eroded surfaces.

The system assigned 0.99% to forests and forest protection belts. These are probably the boundaries with arable land or other deforested plots that are affected by surface erosion.

According to the ratio between surface erosion process [11] and the surface of the basin by categories of land use (Figure 14), it follows that the highest ratio bellows to pastures and hayfields (0.2672), although about 65% of the total surfaces affected by surface erosion return to the arable land. This fact indicates that 26.72% of pastures and hayfields are affected by surface erosion. The next value belongs to arable land with a ratio of (0.1311), which indicates that about 13% of arable land is affected by this process. Forest protection belts, vineyards, orchards follow with (0.0960), and (0.0864) respectively, followed by industrial constructions (0.0413), settlements (0.0146) and forests (0.0290).

For the *gullies*, the current situation is relatively reassuring [12, 13]. According to Figure 15 and Figure 16, most gullies (61.65%) are located on pastures and hayfields, arable land is affected by 35.44% of the total gullies, and about 3% are located on vineyards, orchards, and forests.

Taking into account the ratio between the surface of the gullies and the surface of the study area by categories of land use (Figure 17), the most affected by this process are pastures and hayfields (0.0404), followed by arable land (0.0050), forests (0, 0041), and vineyards and orchards (0.0023).

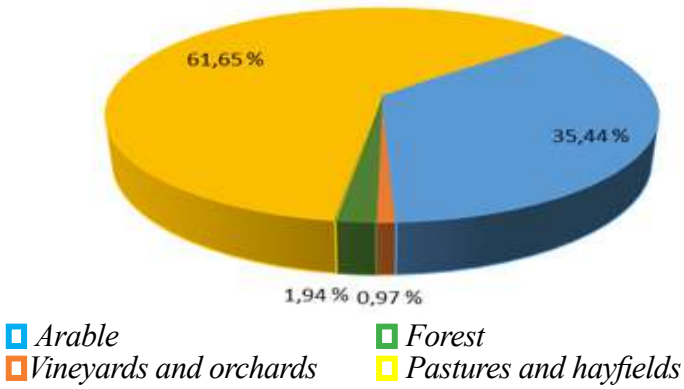


Figure 15. The share of ravines by land use category

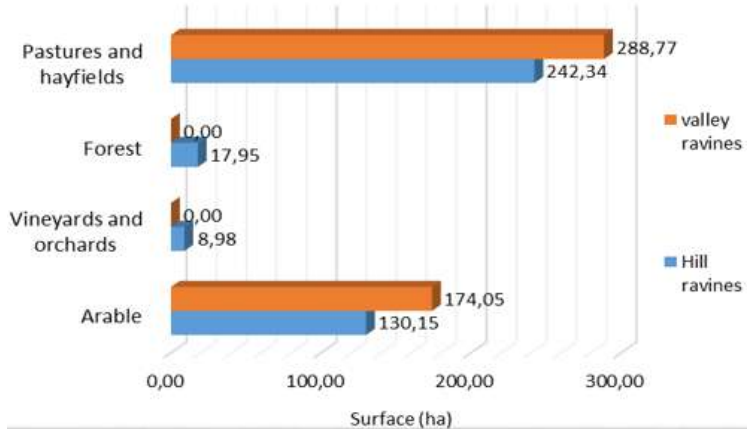


Figure 16. Surfaces affected by ravines by land use category

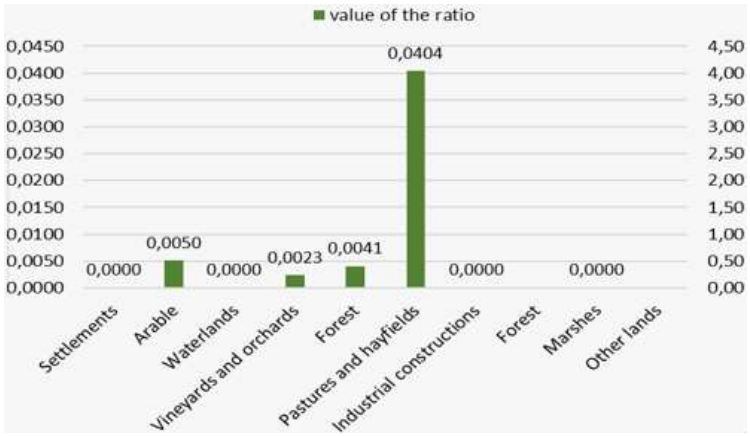


Figure 17. Correlation between land use and ravines

Why the situation with the surfaces affected by gullies is more reassuring?

Because following the percentage ratio we realize that the lowest values reach the surfaces affected by the gullying process.

Conclusions

Considering the geomorphologic conditions of the study area, we selected three geomorphological processes, including the landslides, surface erosion and ravines, to study their impacts on land use/cover diversity and pattern. The research results show that geomorphology not only affects the spatial distribution of the land use/cover pattern but also affects the scope and intensity of human activities.

In conclusion, we mention that agricultural lands occupy 81.96% of the total surface of the surveyed territory, of which about 80% are arable lands, which is above the general average for the Republic of Moldova. The distribution of forest in study area reaches approximately half of the norm established for the Republic of Moldova, which is quite worrying.

The water lands and marshes occupy the lowest areas. In the case of marshes the situation is reassuring. In the case of the water lands, which occupies a little over 1% of the Cubolta River basin's surface, it is far below the average for the Republic of Moldova and it is really not good thing from a lot of points of view (social, economic).

Through the data analysis for every land use category, it was concluded that the pastures and hayfields in the study area are most often associated with the landslide process. This proves that these territories have a relatively low resistance to geomorphological processes. As measures to combat erosion processes, pastures and hayfields can be transferred to another category of land use or to carry out some recreational practices. Most affected by the surface erosion process is arable land. One thing no less important is that this type of land use is also affected by gullies.

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