

**Landslide25\_34****Landslide Processes and Mapping of Their Geoecological Risks within the Yasinia Community, Ukrainian Carpathians**

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**SUMMARY**

This study investigates the development and distribution of landslide processes within the Yasinia Community, located in the Zakarpattia Region of the Ukrainian Carpathians. Using GIS tools, digital elevation models, and field observations, the research identifies the main landslide hot spots and assesses their potential impact on the community's geoecological situation. The findings show that approximately one-third of the community's territory (162,6 km<sup>2</sup>) is affected or potentially threatened by landslides, particularly in the central and northeastern regions, where these processes have a significant negative impact on the environment, infrastructure, and land use. A significant number of large landslides of various types have been identified within the community, some of which reach lengths of over 500 meters and escarpment heights exceeding 25-30 meters, with the highest intensity of development recorded in areas with argillite flysch deposits. The study highlights the need for detailed mapping, the creation of a landslide cadastre, and the implementation of monitoring and preventive management measures to mitigate risks.

**Keywords:** landslides, geoecological threats, argillite flysch, gravitational processes, geoinformation analysis, Yasinia Community.

## Introduction

An important prerequisite for the sustainable development of newly established territorial communities in the Ukrainian Carpathians is the efficient utilization of natural resources and the stabilization of the ecological situation, with geoeological threats arising from contemporary physico-geographical processes constituting a critical factor. One of the largest and most promising mountain communities in terms of development within the Zakarpattia Region is the Yasinia Settlement Territorial Community, situated in the Rakhiv District at the headwaters of the Chorna Tysa River basin. Currently, the community's administration is actively working on the formulation of a development strategy and has initiated the preparation of a Comprehensive Spatial Development Plan, which, among other tasks, requires an in-depth analysis of the dynamics and spatial patterns of hazardous processes within the community's territory. Among the physico-geographical processes in the area, landslides represent the most significant threat to ecological stability, sustainable development, and territorial planning. The dominance of argillite flysch in the geological structure, together with the presence of genetically and morphologically complex erosion-denudation geocomplexes, has resulted in large-scale landslide activity across the territory. Consequently, the mapping and spatial analysis of landslide development zones, along with an assessment of their potential impact on the geoeological situation of the Yasinia Community, has become an urgent and highly relevant task.

## Method

The investigation of the development patterns and spatial distribution of landslide processes within the Yasinia Community is based on methods of morphological relief analysis and geoinformation processing of spatial data, complemented by the study of various archival sources and materials from the authors' long-term fieldwork. For surface modeling and morphometric analysis of the relief aimed at identifying landslide clusters (hot spots), multiple data sources were utilized: elements of the digital topographic map of the Yasinia Community at scales of 1:25 000 and 1:10 000 (Yasinia ..., 2025); technical reports from geological and geomorphological surveys along with corresponding cartographic materials at a scale of 1:50,000 and sheet L-34-VI (Baia Mare) of the State Geological Map at a scale of 1:200 000 (State ..., 2009); scientific studies on the landscape differentiation of geological and geomorphological processes in the region (Karabiniuk et al., 2020; Hostiuk et al., 2021); as well as archival records from the Department of Land Relations and Spatial Development of the Yasinia Settlement Council (Yasinia ..., 2025) and the results of the authors' own landscape-ecological field research conducted as part of a large-scale landscape survey of the Chorna Tysa River basin. The geoinformation data processing and geological map vectorization were carried out using licensed ESRI ArcGIS 10.8.1 software (License No. 681999-1) at the Department of Land Relations and Spatial Development of the Yasinia Settlement Council, while the compilation of the cartographic materials was completed at the Faculty of Geography of Uzhhorod National University.

## Examples

The Carpathian region is one of the most landslide-prone areas in Ukraine. Within the Zakarpattia Region, the total area of 3 278 landslide hot spots covers 385 km<sup>2</sup> (Shtohryn et al., 2020). Currently, a variety of landslide types have been recorded within the Yasinia Community, among which block sliding, slides, flows, spreads, topples, complex and others predominate (Slyvka, 1969; Yasinia ..., 2025). By the early 21st century, over 90 large landslides of various types had been identified within the community, the majority of which are localized in the central part of the Chorna Tysa River basin, where argillite flysch is characteristic of the geological structure (Shtohryn et al., 2020). The central part of the Yasinia Community is represented by the Yasinia Valley, which is characterized by gentle and sloping hills, complicated by landslide forms and an erosion-gully system. This area includes the village of Yasinia and its surrounding settlements, such as Stebnyi, Svydovets, Lopushanka, Kryvorivnia, and others. In the morphological

structure of the hollow, river terrace complexes of the Chorna Tysa River and its largest tributary, the Lazeshchyna River, play a significant role. The main settlements and infrastructure are concentrated in their valleys. Agricultural land in the form of hayfields and pastures is located on ancient high terraces, which are undergoing active degradation due to the gully-balk network and landslides. The smoothed nature of the Yasinia Valley's relief and the intensive development of erosion-denudation processes are determined by the presence of fine-rhythmic argillite flysch from the Krosno geological structural-facial zone.

As a result of the study and morphological analysis of the relief using GIS tools, the largest areas of development of relict and currently active landslides within the Yasinia Community have been identified. These are manifestations of the functioning of erosion-denudation geocomplexes and have a negative impact on the geoeological situation in the community. The largest areas of large-scale landslide slopes within the community are located in the valleys of the Chorna Tysa, Lazeshchyna and Lopushanka rivers, as well as the Stanyslav, Stebnyi ta Repechno streams. The predominant features here are relict landslide zones, which are expressed in the current relief as hilly stepped slopes with a well-developed cover of grassy vegetation. On the background of these ancient landslide slopes, small areas of modern landslide processes are also located. These are primarily situated at the heads of gullies with permanent watercourses or at the lower parts of the slopes of river valleys. For example, a large landslide, more than 500 meters in length, is actively developing in the right bank of the Chorna Tysa River within the Yasinia village area (Havrylets tract), where its intensive development began in the early 21st century. The height of the upper escarpment is over 25-30 meters. Morphologically, this landslide is complex and formed on powerful layers of argillite flysch. Before the active phase of development, the area of the current landslide site was used for haymaking. Today, its functional purpose has been lost due to the complex morphometry of the surface, the presence of deep cracks, and deformations of the landslide mass, which are particularly dangerous during summer rainfall. The main part of the landslide mass is covered with grassy vegetation, which does not securely anchor the surface.

The largest landslide cirques within the Yasinia Community have been identified on the right-bank slopes of the Lazeshchyna River and the Repechno Stream. The width of some of these cirques reaches 300-500 meters, with lengths exceeding 600 meters (the cirque on the slopes of Plytuvata Mountain has a length of 861 meters). The height of the escarpment is approximately 50-60 meters (down to the lower step). In general, the landslide cirque is stabilized by grassy and shrub vegetation. However, fresh escarpments have developed on the steep rear wall, and the bottom contains uncovered accumulations of landslide debris. Small ponds and bogs are often found on the wide landslide steps. A similar character is exhibited by numerous landslide cirques located in the foothill areas of the right-bank slopes of the Repechno Stream. Their dimensions vary within the following range: width 80-200 meters, length 300 meters, and escarpment height ranging from 15-20 to 50 meters.

A distinctive feature of the Yasinia Community is that its development is located not only on leveled, terraced river valleys but also high on the slopes of watersheds. As a result, landslide hot spots frequently come into direct contact not only with agricultural lands but also with residential and public buildings. For example, in the Kostyrivka tract (Yasinia), on the stepped slopes of the watershed between the Chorna Tysa River and the Lopushanka Stream, extensive zones of ancient landslides with signs of current activity are present. Their maximum width exceeds 550–600 m, and their length is around 500 m. The surface of the landslide bodies is covered with grassy vegetation and remains persistently waterlogged after rainfall periods. At lower hypsometric levels, beneath the landslide cirques, small patches of land host private houses and hayfields, which are under potential threat from further landslide activity. Smaller landslides with deeply incised bodies are also widespread within the Yasinia Community. During their evolution, these landslides often acquire a funnel-like shape. Such sites are characteristic of the Stebnyi River basin (a right tributary of the Lazeshchyna River), which is notable for its elongated drainage catchment and clear association with the argillite flysch zone. More than 25 large landslides have been identified within this

basin. Most of them are characterized by turf-covered slopes with a well-developed block structure, with widths generally ranging between 200–250 m and lengths up to 200 m.

The most significant negative impact on the functioning and development of the Yasinia Community comes not from ancient landslides, which are often relatively stable, but from currently active landslide hot spots. These are characterized by intensive dynamics and develop in close proximity to relict landslides, and less frequently, on fresh hot spots. Active modern landslides are widespread on the right bank of the Lazeshchyna River, in the basin of the Lopushanka River, the Svydovets Stream, and along the Yasinia-Yablonytsia road, where loose masses of mountain rocks are constantly sliding. The largest active landslide within the Yasinia Community today is the one in the Ropsha locality of Yasinia village, which reactivated on 25 June 2020, triggered by intensive over-wetting of argillite layers due to anomalous rainfall. Its total area is 0,1218 km<sup>2</sup> (830 × 250 meters) (Yasinia ..., 2025). According to the technical report from the field survey, experts estimate the escarpment height at approximately 20 meters, with the depth of the landslide body ranging from 25-30 meters (Yasinia ..., 2025). The deformations of the landslide mass underscore its complex structure, consisting of diluvial landslide clays and silty clays, which are displaced from the underlying layers of Paleogene flysch. As a result of the landslide's development, a depression was formed in the lower part, below the escarpment, measuring 20×15 meters, which was filled with water for a prolonged period. The horizontal displacement of the landslide body reaches about 30 meters, forming a network of crack networks with intermediate escarpments ranging from 1,0 to 3,0 meters in height and expanding up to 0,5 meters (Yasinia ..., 2025). In the lower, tongue-like part of the landslide mass and along both flanks, extrusion ridges of varying size have formed, ranging from 0,2-0,3 meters to 3-4 meters in height. This landslide is the largest within Yasinia village since the early 21st century. Evidence of its continued potential threat is the presence of numerous secondary cracks and escarpments up to 50 meters above the main escarpment, with heights ranging from 1,0-1,5 meters and lengths of 50-70 meters across the slope. This indicates the foundation for the further development of the landslide and its potential for significant expansion. Furthermore, within a 30-120 meter radius of the landslide's potential impact zone, there are five residential buildings and several agricultural structures.

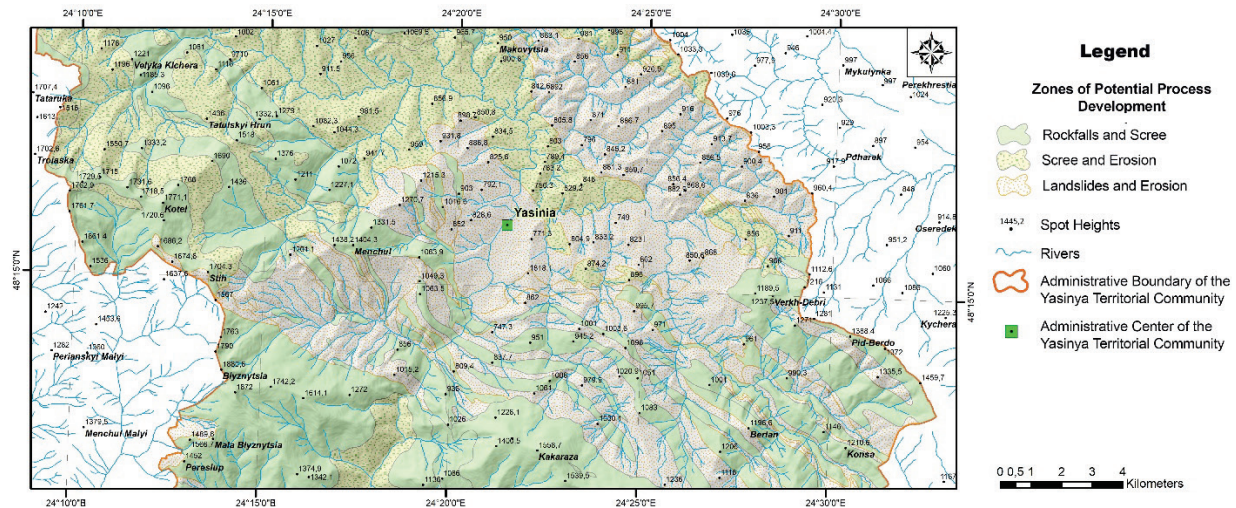
## Results

The analysis of landslide processes within the Yasinia Community demonstrates a direct dependence on the geological structure and the characteristics of the underlying rocks dominated by argillite flysch. Based on geoinformation analysis of geological data, the identification and processing of landslide development sites, spatial analysis of both relict and currently active landslide hot spots, as well as the modeling of key relief parameters, a map of potential distribution of geological and geomorphological processes in the Yasinia Community was created (Fig. 1). This map essentially illustrates the spatial differentiation of the community's vulnerability to the development of dominant hazardous geological and geomorphological processes, represented by three main combinations: rockfalls and screes, screes and erosion, and landslides and erosion.

## Conclusions

The spatial nature and dynamics of landslide processes within the Yasinia Community are determined by the combination of geological and morphological factors. The key role is played by the distribution of argillite flysch, in combination with the features of the relief, which create favorable conditions for the activation of slope processes. The use of modern GIS tools, analysis of digital elevation models, field observations, and the processing of available geological and cartographic data have enabled the identification of the largest landslide hot spots and the development of high-quality cartographic material regarding their potential distribution. The obtained results show that approximately one-third of the community's territory (162,6 km<sup>2</sup>) is either currently affected or potentially threatened by landslides in combination with erosion processes. Special attention is required for the central and northeastern regions

of the community, where the manifestations of these processes are particularly hazardous and could significantly affect the environmental state, infrastructure safety, and land use. The identified patterns confirm the need for detailed mapping and study of all landslide-prone areas within the community, the creation of a landslide cadastre that takes into account the genetic landscape-ecological features of the area and the established land use system, as well as the implementation of monitoring studies.



**Figure 1** Map (fragment) of the potential distribution of dominant geological and geomorphological processes within the Yasinia Community, Zakarpattia Region.

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