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# Spatial analysis of the relation between the distribution of dangerous exogenous geological processes and landscape hydrogeological complexes in Transcarpathian

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## SUMMARY

The impact of hydrogeological conditions on the formation of dangerous exogenous geological processes (EGP) (landslides, mudflows, underflooding) for the territory of the Transcarpathian region is considered. Analysis of the localization of the EGP of different types in relation to landscape-hydrogeological complexes allowed to establish certain patterns of their distribution, which, in turn, suggests the need to involve hydrogeological zoning by the groundwater formation as a static factor influencing the development of EGP for creating predictive models of exogenous geodynamical activity.

**Introduction**

The problem of the safety of population and a lot of economic objects within the areas of dangerous exogenous geological processes (EGP) occurrence is one of the main socio-ecological problems of today due to the losses caused by these processes. EGP, caused by natural and man-made factors, the role of which often increases when they are combined, do significant damage to the environment for the territory of Transcarpathian. Unsystematic deforestation in the lower parts of the slopes, near settlements and roads, construction of dirt roads for timber contribute to intensification of EGP in addition to tectonic faults, flysch and clays in the geological records, flooding of slopes, geomorphological features (Ivanik, 2008; Kuzmenko and Chepurna, 2014; Chepurna and Chepurnyi 2015; Kuzmenko et al., 2016). Natural exogenous processes are dominated by landslides, mudflowes and underflooding (fig. 1).

The purpose of this study is to assess the relation between the occurrence of different types of dangerous EGP and the hydrogeological conditions of the territory by overlay analysis of cartographic layers of EGP localizations and hydrogeological and hydrological zoning.

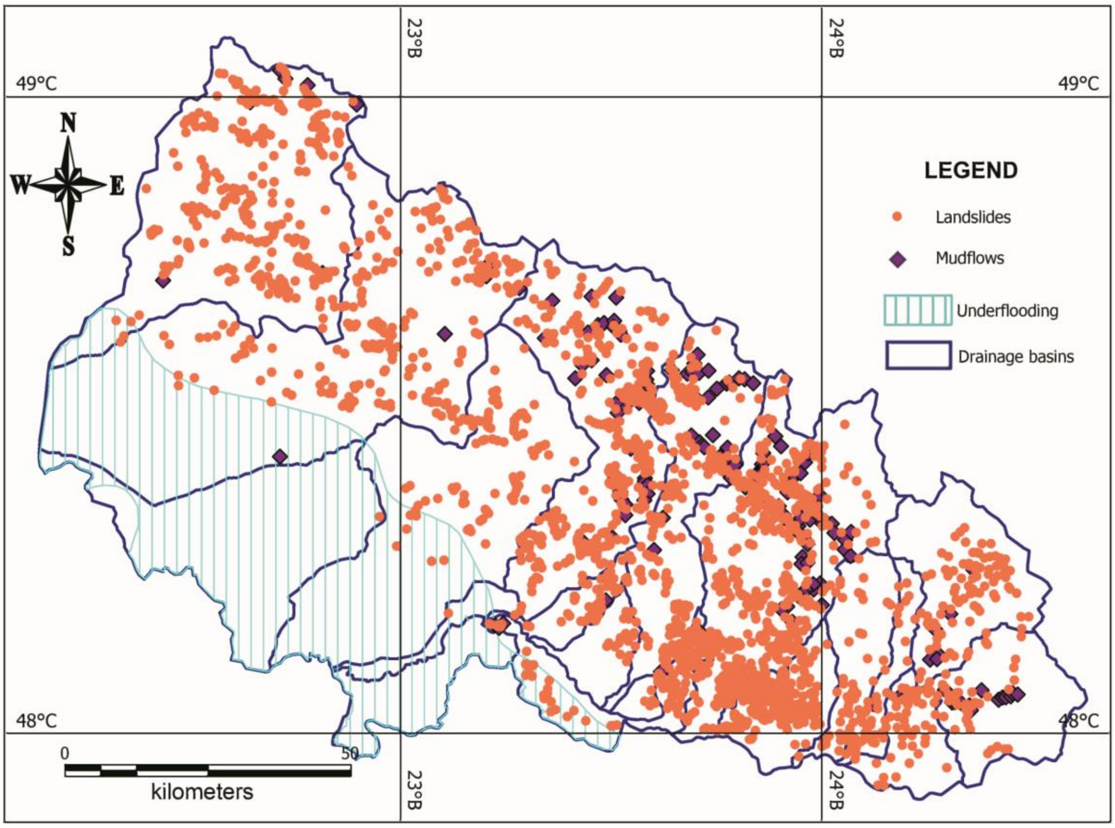


***Figure 1.*** *Localizations of EGP within the studied area*

**The specifics of hydrological and hydrogeological conditions of the studied area**

Territorially, Transcarpathian is coordinated with the Ukrainian part of the Tisza River basin. Significant differences in altitude, difficult terrain and geological structure of the mountains, high rainfall and rapid changes in climatic conditions contribute to the development of floods. Due to the small slopes of the plain rivers floodwaters overflow, flooding large areas. Floods, under certain conditions, lead to catastrophic consequences, causing significant damage to the economy of the region. In addition, they cause and exacerbate the manifestation of dangerous geological processes, such as landslides, mudflows, erosion, karst, underflooding and others. The groundwater of the Ukrainian part of the river basin forms a single artesian basin, which covers the territory of Hungary and, in part, Slovakia and Romania. Groundwater transits across the plains of Transcarpathian outside Ukraine, and the Pannonian Basin in Hungary is a regional area for their unloading.

Taking into account the experience of previous research on this topic (Heruk et al., 2017; Chen et al., 2019; Guo et al., 2020; Shtohryn et al., 2020), catchment basins of tributaries of the Tisza River were selected as territorial units for assessing the impact of EGP on the geological environment within the studied area and thematic mapping (Fig. 1).

Landscape hydrogeological complexes (LHGC) are considered as azonal units of hydrogeological zoning, which reflect the stratigraphic features of the conditions of groundwater formation (the activity of which is an important factor in the development and activation of EGP) (Ruban and Nikolishina, 2005).

In general, within the study area there are 10 types of LHGC (4 plain and 6 mountain among them) (Fig. 2), namely:

- 4(a)7 – plain type; the aeration zone and the water-bearing stratum are composed of sands with layers of loams, sands and clays, lined with different-age clays or cretaceous and marl rocks;
- 4(b)8 – plain type; the aeration zone and the water-bearing stratum are composed of sands with layers of loams, sands and clays, which lie on the clay rocks of the weathering crust or dense crystalline rocks;
- 7(b)14 – plain type; the aeration zone and the water-bearing stratum are composed of rocks of the fractured zone of the weathering crust (granites, breakstone, rubble). Lined with weakly fractured crystalline rocks;
- 8(a)15 – plain type; the aeration zone is composed of multi-grained sands (pebbles) with layers of loams, sands and clays. The water-bearing stratum, having a similar structure, is supplemented in the lower part by limestones. The confining stratum is represented by limestones, marl-chalk rocks or clays;
- M(1) – mountain type; the aeration zone and the water-bearing stratum are composed of sandstones, argillites, marls, limestones, conglomerates, covered by a low-thickness layer of clay-sandy-gravelly deposits. The confining stratum is represented by dense argillites, conglomerates, limestones, etc;
- M(2) – mountain type; the aeration zone and the water-bearing stratum are composed of block-gravelly and loamy formations with the inclusion of pebbles. The lower part of the water-bearing stratum is supplemented by sandstones, argillites, marls, limestones and conglomerates. The confining stratum is represented by dense argillites, conglomerates, limestones;
- M(3) – mountain type; the aeration zone and the water-bearing stratum are composed of pebbles with sand-loam aggregate, covered with clay-loam formations with fragments of primary rocks. The lower part of the water-bearing stratum is supplemented by sandstones, argillites, marls, limestones and conglomerates. The confining stratum is represented by dense argillites, conglomerates, limestones;
- M(4) – mountain type; the aeration zone and the water-bearing stratum are composed of fractured basalts, andesite-basalts, liparites and tuffs. The confining stratum is represented by monolithic andesitic basalts;
- M(5) – mountain type; the aeration zone and the water-bearing stratum are composed of block-gravelly and loamy formations with the inclusion of pebbles. The lower part of the water-bearing stratum is supplemented by fractured basalts, andesites, liparites and tuffs. The confining stratum is represented by monolithic andesitic basalts;
- M(6) – mountain type; the aeration zone and the water-bearing stratum are composed of pebbles with sand-loam aggregate, covered with clay-loam formations with fragments of primary rocks. The lower part of the water-bearing stratum is supplemented by fractured basalts, andesites, liparites and tuffs. The confining stratum is represented by monolithic andesitic basalts.

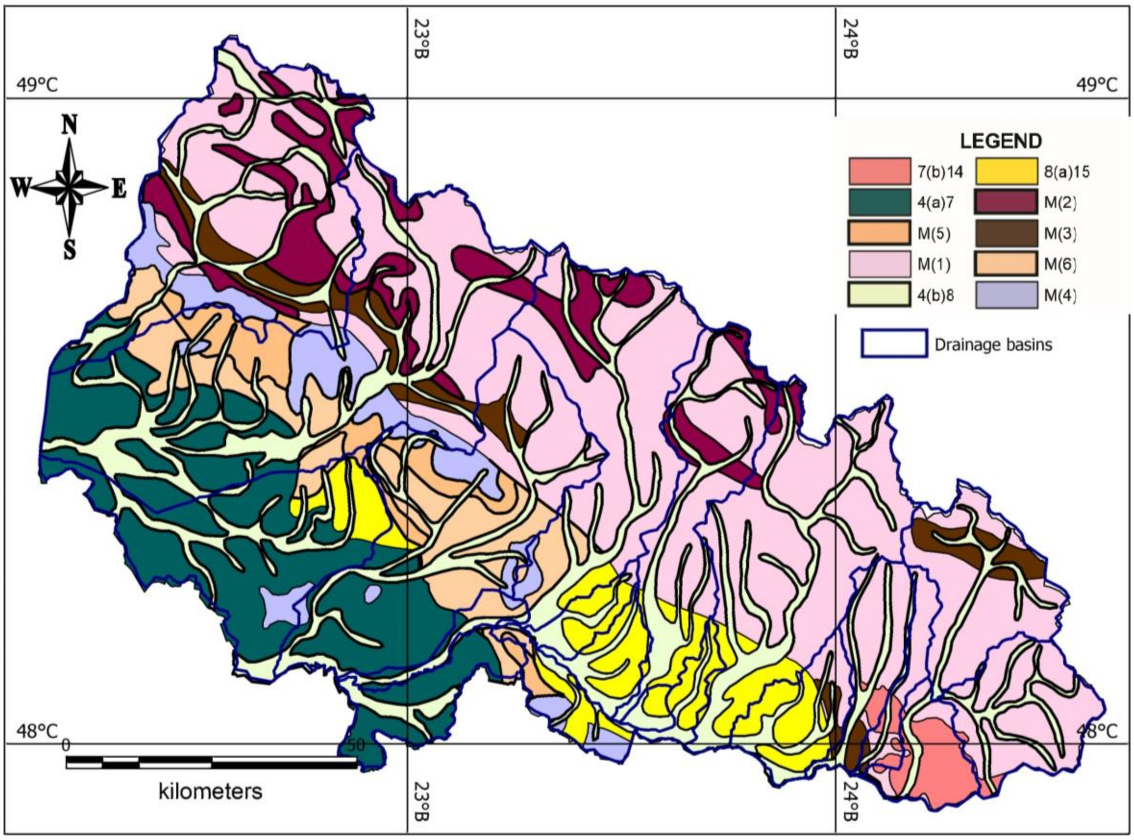


***Figure 2.*** *Zoning of the studied area by type of predominant LHGC*

**Spatial analysis of the EGP distribution and the different types of landscape-hydrogeological complexes within the sub-basins of the Tisza River**

To compare the intensity of EGP activation (landslides, mudflows, underflooding) in some catchments and LHGCs, it is necessary to territorially standardize the distribution of EGP manifestations. To do this, we used a quantitative characteristic that reflects how the territory is affected by the dangerous EGP – contrast coefficient (Ri), which is determined by the formula:

$$R_i = \frac{N_i \cdot \sum S_i}{S_i \cdot \sum N_i} \qquad (1)$$

where $N_i$ – the quantity of registered EGP (or area of flooded territories) within some river basin (or some LHGC); $\sum N_i$ – the total quantity of registered EGP (or total area of flooded territories) within the studied area; $S_i$ – the area of some river basin (or some LHGC); $\sum S_i$ – total area of the studied area.

The total intensity of dangerous EGP occurrence on territory can be calculated as the sum of all contrast coefficient (landslides, mudflows, underflooding) for each individual catchment area or type of LHGC.

**Conclusions**

The obtained results of the spatial analysis show that LHGC of mountain type M (1), situated on the northeastern mountainous part of the region, and LGGK plain type 4(b)8 , which is typical for river valleys and is common for all catchment areas of the Tisza tributaries, have the largest spatial distribution within the studied area (35.9% and 20.1% of the total area, respectively).

Regarding the impact of LHGCs by EGP of different types, the highest values of contrast coefficient for landslides (R =3.17) were obtained in the case of LHGC 8(a)15, mudflowes (respectively Ri=1.73 and Ri=1.63)) – LHGCs M(1) and M(2), underflooding (R =4.04) – LHGC 4(a)7. The generalization of the results of the analysis shows that the river basins of Borkut, Tereblia, Teresva and small rivers of the southwestern part of the studied region, where these LHGCs predominate, are the most vulnerable to the dangerous EGP.

The coordination of the EGP localizations with such taxons of hydrogeological zoning as LHGC, defined during the spatial analysis, confirms the expediency of using this hydrogeological zoning as a spatial basis for creating regional prognostic models of EGP occurrence.

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