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ASSESSMENT OF LANDSLIDE HAZARD RISKS ON THE EXAMPLE OF THE LAND CADASTRE OF KOSIV DISTRICT

The purpose of the research presented in this article is to analyse landslide hazards by assessing the impact of the natural component of factors on land use within the Kosiv district of the Ivano-Frankivsk region. The increasing number of negative consequences of landslide processes in the study area, and especially in the Carpathian region of Ukraine, requires the creation of new approaches to land resource assessment and civil engineering to reduce the negative impact of landslides on the environment and human activities. Methods. Landslide processes were studied using geophysical methods, GPS and geostatistical methods of data analysis. Based on the created mapping layer of the land cadastre and the landslide hazard map for Kosiv district, a vector analysis was performed to assess the risk in each area according to its cadastral number. Results. The environmental and geological risk of the natural component of landslide hazard factors was calculated using geoinformatics and geostatistical analysis tools with the use of QGIS. An important result of the research is the creation of landslide risk maps of land plots based on data from the State Land Cadastre using the Kadastr.Live Toolbar plugin. Scientific novelty. For the first time an analysis of the natural component of landslide hazard risks for the territory of Kosiv district was carried out as a basis for the assessment of such risks for individual cadastral zones. The regulatory and monetary assessments were clarified based on individual territories, for conducting economic activities that require hydrogeological research or changing the intended use of land.. Practical significance. By applying the methodology of dividing landslide risk assessment factors into natural and anthropogenic components, it becomes possible to identify areas within the study area with the highest probability of landslide development and activation. This method helps to study the characteristics of natural factors and is useful in assessing the risk of landslides..

Key words: landslide, cadastre, land plots, risk

Introduction

To date, many geographical information systems have been developed and implemented. They analyse the EGP comprehensively and are based on spatial and temporal forecasts. However, the components of the EGP process, especially the spatial component, have different dynamics in different regions and different factors contributing to their development. Therefore, the search for methods to analyse landslide processes, as one of the most common types of ESG, is an important stage of research based on the factor load on landslide development processes within built-up areas or those used for other economic purposes. Modern GIS allows a wide range of geostatistical and spatial analyses. The capabilities of interoperable datasets greatly enhance the use and analysis of different research models.

The study of landslides, forecasting and mitigation of their negative impacts is a key item on the agenda of the World Landslide Forum [Casagli et al., 2022], as is the impact of climate change through increased precipitation on landslide activation. In works [Santangelo et al., 2022; Snitynskyi et al., 2020; Ivanik et al., 2019] emphasise the importance of river erosion and tectonic factors in the occurrence of natural hazards in the Ukrainian Carpathians, including landslides.

It is important to consider the impact of natural factors, especially in regions with high groundwater levels. The work of [Tymkiv, Kasiyanchuk, 2018] addresses the problem of studying data with gaps.

The use of photogrammetric methods based on RPV data [Puniach, et al., 2018] allowed to identify factors affecting the accuracy of surveying and displaying updated cadastral data for areas where landslide processes are developing.

In works [Zweifel, et al., 2021] investigates the driving forces of shallow landslides in Switzerland, considering regional differences in territory, geological and geomorphological conditions and climate.

The resulting mapping material is presented in [Pontes, et al., 2021] as an important technical contribution to landslide risk management and land use planning to reduce geotechnical problems in the field.

An article [Wood, et al., 2022] summarises new mixed methods and a scalable approach to risk prioritisation in the context of an organisation with multiple hazards, multiple objectives and multiple criteria.

The authors of [Sestras, et al., 2022] have used long-term observational data obtained through geodetic monitoring to predict future movements of landslides and erosion. They have developed preventive strategies based on a new methodology that combines commonly available geoanalytical tools and techniques. This synthesis of information on landslide and erosion dynamics will help in preventing potential disasters..

Timely and rational landslide prediction is crucial for the design and development of critical infrastructure that can protect human life in earthquake-prone regions, as explored in [Panagiotis, et al., 2022]. This study presents a new hybrid coseismic landslide prediction model (COLAFOS) that considers three parameters, namely, average slope, exposure and geological form types.

The authors of [Sestras, et al., 2022] have used long-term observational data obtained through geodetic monitoring to predict future movements of landslides and erosion. They have developed preventive strategies based on a new methodology that combines commonly available geoanalytical tools and techniques. This synthesis of information on landslide and erosion dynamics will help in preventing potential disasters..

In [Marr, et al., 2023], the authors investigated an important feature of various types and processes that can also affect infrastructure and land use planning, such as slow-moving landslides, which are often underestimated. Therefore, the study of areas affected by slow-moving landslides provides an opportunity to better understand the spatial and temporal patterns of these processes, their forcing, mechanisms and potential risks.

The use of geographic information systems for spatial analysis of the probability of occurrence or intensification of EGP is aimed at solving various tasks, from administrative management to prevention or mitigation of the consequences of emergencies.

In the Ivano-Frankivsk region, landslides affect almost 2% of the territory, covering an area of about 250 km^2, with the total number of landslide-prone areas exceeding 640, 80% of which are related to economic activity.

The main natural causes of landslides are riverbank erosion, seismicity and increased slope steepness. The mountain and foothill areas of the region suffered the most from the massive landslides, mudflows and river erosion in 2010-2012.

The landslide process mainly affected Verkhovyna district - the territory of the Rika River basin, with landslides covering about 50-60% of the territory; Kosiv district - the town of Kosiv and the settlements of the Rybnytsia and Liucha River basins; Kolomyia district – the right bank of the Prut river Sniatyn district – the villages of Sniatyn and Novoselytsia.

The research aims to analyse the impact of landslide processes by assessing the risk of their development in individual locations based on the land cadastre.

Purpose

The purpose of the research presented in this article is to analyse the landslide hazard by assessing the impact of the natural component of factors on land use within the Kosiv district of the Ivano-Frankivsk region. The increasing number of negative consequences of landslide processes in the study area, and especially in the Carpathian region of Ukraine, requires the creation of new approaches to land resource assessment and civil engineering in order to reduce the negative impact of landslides on the environment and human activities.

Source data

The study processed spatial database of landslides (Geoinform of Ukraine) for Ivano-Frankivsk oblast and the report on geological exploration of the subsoil No. 29/10-34 [Kuzmenko & Shtohryn, 2010].

To assess the landslide hazard risk of land plots, data from the State Land Cadastre were used applying the Kadastr.Live Toolbar plugin and the map of ecological and geological landslide risk assessment of Ivano-Frankivsk region [Kasiyanchuk, 2016; Shtohryn, et al., 2020].

Hydrogeological conditions for the formation of landslide processes within the study area

The development of geological processes in the Carpathians is subject to certain regularities that characterise the influence of both natural and anthropogenic conditions and factors. The first group includes climatic factors that determine the intensity of weathering processes and the precipitation regime associated with landslide flows.

The Kosiv district (Fig. 1) is located in the lowlands of the Pokuttya Carpathians and the erosive interfluves of the Precarpathian region in the inner and outer zones of the Precarpathian trough.

Neogene sediments are represented by the Tortonian (Tyraska, Kosivska formations) and Sarmatian (Dashava formation) Miocene levels.

In the Outer Trough Zone, the Tyras Suite is a widespread layer of gypsum and anhydrite. It is a pack of chemogenic rocks, sometimes with clay beds, only 40m thick. The thick sandy-clay layer above the gypsum of the Tyras Formation is the Galician Series, which includes the Kosiv Formation with three horizons - the Verbovets, the Prut and the Kolomyia. The Kosiv Formation consists of dark-grey, thin-bedded clays, siltstones, grey sandstones with interbedded clays and gravels in the upper part of the section. The lower part of the formation is characterised by the presence of tuffs. The Verbovetsky Formation consists of grey clays with thin beds of sandstones and tuffs.

The entire stratum above the Kosiv Formation is called the Dashava Formation. The Kosiv Formation corresponds to the lower part of the Galician Series and the Dashava Formation to its upper part. In terms of age, the Kosiv Formation belongs to the Upper Tortonian and the Dashava Formation to the Lower Sarmatian. The Lower Sarmatian and Middle Sarmatian strata are undivided (N1s1-2) and consist of micaceous clays, siltstones and sandstones with a total thickness of 15 to 55 m. The clays are predominantly carbonaceous [Hodunko, 2009].

According to the engineering and geological zoning scheme, this is the area of the southern Pokutsko-Bukovyna foothills. The lithology is freshwater coal-bearing facies.

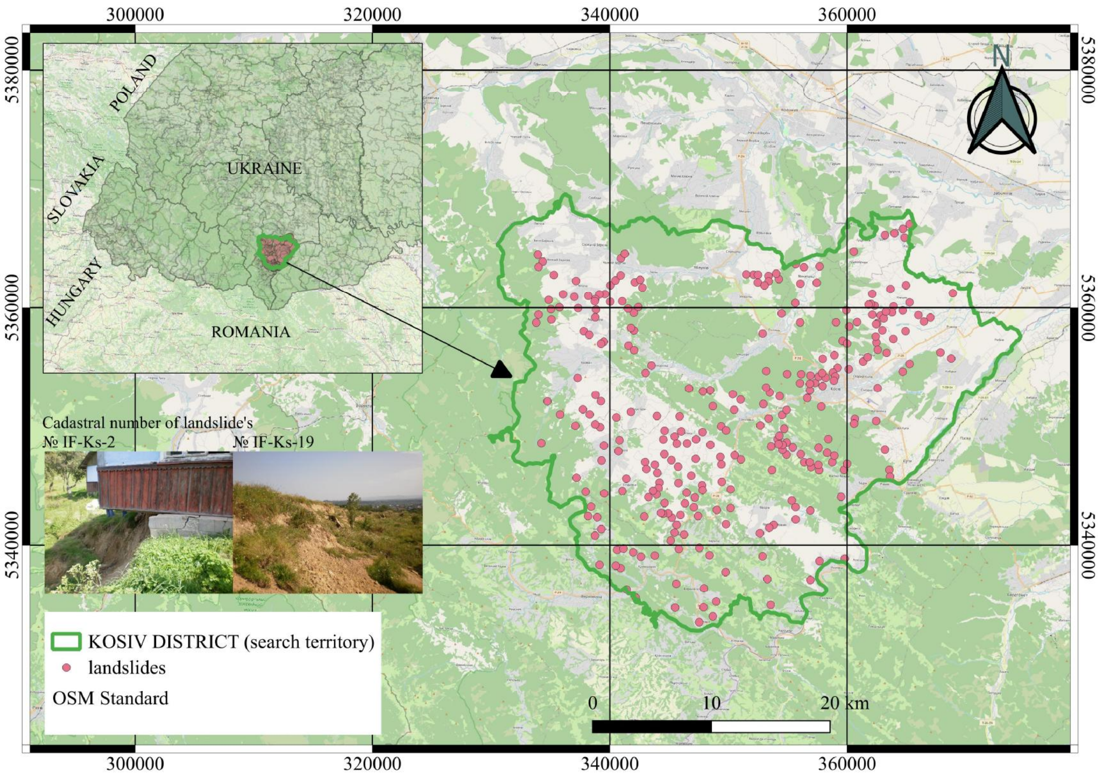

Fig. 1. Map of landslide processes in the study area

According to the hydrological zoning scheme of Ukraine, the entire district lies within the Dniester-Prut hydrological region. The villages of the studied Kosiv district (Verbivtsi, Kobaki, Rozhniv) are located in the basin of the Tarnovets River, which flows into the Rybnytsia River, a right tributary of the Prut River.

The present relief of the Kosiv district is the result of tectonic movements and the continuous action of exogenous factors. Landslides are mainly confined to the slopes of large river valleys. The development of these processes is facilitated by lithological, tectonic [Shtohryn, et al., 2021], geomorphological and hydrological conditions. The main ones are the following:

1. Significant waterlogging and wetting of slopes due to high precipitation, disruption of the conditions of occurrence and integrity of slope rocks as a result of tectonic activity, low position of the erosion base resulting in a difference in height between the slope edge and the slope bottom, change in the regime of aquifers and their outcrops. The majority of landslides are confined to zones of longitudinal and transverse tectonic faults. Groundwater often causes large masses of rock to slide. The landslide starts in the upper part of the slope. Predominantly cirrus shape. Landslides occur in groups.

2. Physical and chemical weathering processes - these phenomena are mainly confined to the indigenous sedimentary rocks of rock outcrops, coastal cliffs, gully sides and slopes of large canyons. Weathering is also facilitated by rock texture, fracturing and other rock properties.

The most widespread are Quaternary sediments, of which the main type is eluvial deposits, 1-2 m thick. Eluvial formations are most developed in elevated, more or less compacted areas of the mountainous relief; eluvial areas are also preserved on wide, gentle slopes with a favourable ratio of weathering and abrasion. Another type of Quaternary accumulation is alluvial deposits associated with river activity. They are common in modern and ancient valleys and on river terraces. The composition of alluvial river sediments varies. They include sandy clay, especially sandy pebbles, loams and clays. Intense weathering leads to the destruction and decomposition of rocks into their components. The native rocks are covered with a layer of the products of their destruction, and the slopes of the mountains are smoothed. The sediments that accumulate on the slopes and at the foot of mountains as a result of the displacement of the products of rock destruction form deluvial deposits. Deluvial sediments have a wide distribution area and are deposits of small fragmentary products of plane flushing by melted snow and rainwater. The formation of deluvial sediments is strongly influenced by terrain, weathering processes, vegetation cover and other natural phenomena that cause the destruction and movement of weathering products. The deeply dissected relief intensifies rock erosion on slopes and contributes to the accumulation of thick layers of sediment at the foot of ridges. The thickness of the alluvial deposits in the study area ranges from 1 to 5 m, increasing to 10-15 m in places. The composition of the alluvial-deluvial rocks is dominated by loams [Hodunko, 2009].

Most landslides have a complex structure with morphologically distinct areas of denudation, transport and deposition of landslide material. The sliding process is greatly facilitated by surface moisture in the loose slope cover. The landslide masses are displaced in the form of small, overlapping scales of intensely crushed clays or mudstones with sandstone fragments. The thickness of landslide deposits is measured in metres. Landslides penetrate to great depths, leaving a characteristic imprint on the morphology of the slopes. Genetic types of landslides are flows. One type of rock mass movement is a water-plastic flow of clayey rocks on a prepared surface [Kozak, 2010].

Research Methodology

Field research and desktop data processing

The study of landslide processes was carried out using geophysical methods, such as the method of vertical electric soundings, and the method of the natural pulsed electromagnetic field of the earth with GPS reference [Kuzmenko & Shtohryn, 2010]. Based on the created database we calculated the factor characteristics, and probability indicators of the development of landslide processes using the QGIS software.

The Kadastr.Live Toolbar plugin uses the QGIS application to search for the location of a parcel by cadastral number using the Kadastr.Live resource API. Additional features include viewing data about the parcel in Kadastr.Live and Land.gov.ua, and checking the area of the parcel using information from Kadastr.Live. The plugin was developed within the Open Spatial Planning Tools for Ukraine project. Based on the generated cadastral mapping layer and landslide risk map for Kosiv district, a vector analysis was performed to assess the risk in each plot according to its cadastral number.

Assessment of the natural component of landslide risk

The main task of statistical data analysis is to divide groups of factors into natural and anthropogenic components. Based on the results of the analysis, the groups of factor characteristics are distributed according to the law of distribution: the law of normal distribution - natural, lognormal - anthropogenic component. A separate important stage of the study is the estimation of the contribution (information content coefficient) of the characteristics of individual factors to the process of landslide development and activation [Kuzmenko et al., 2016]

The landslide hazard assessment of the natural component of factors was conducted according to the methodology [Kasiyanchuk, 2016]:

1) identification of natural temporal factors influencing landslide development (Table 1);

2) estimation of statistical parameters of the sample;

3) normalisation of data series to make them dimensionless;

4) calculation of the function of the mutual correlation between the characteristics of factors influencing landslide development with the calculation of informativeness - contribution of each factor Rпр (1) [Kuzmenko et al., 2016]:

$$R_{np_j} = \frac{\sum \left| r_{i,j} \right|}{\sum_j \sum_i \left| r_{i,j} \right|} \cdot 100\%, \qquad (1)$$

where: ri,j – is the coefficient of pairwise correlation between i, j variables in the matrix of correlation coefficients of the factor characteristic;

5) calculation of an integral indicator that considers the complex effect of all factors influencing landslide development (2) [Kuzmenko et al, 2016]:

$$\Phi_i = \sum_{j=1}^{m} X_{ij}^{norm}, \qquad (2)$$

where: m – the number of time factors, i - the year of observation. implementation of a long-term time forecast.

Research results

Ecological and geological risk assessment of landslide hazard in Kosiv district

According to the classification, the vast majority of landslides are plastic, structurally plastic, and those associated with rock collapse. The characteristics of plastic landslides are closely related to the weathering crust and its water saturation. Landslides are associated with residual riverine clay formations and landslide deposits. According to this mechanism, plastic displacement is manifested in the form of visco-plastic deformation. Structural-plastic faults are deluvial frontal blocks with plastic displacement.

When analysing the data [Kuzmenko & Shtohryn, 2010], it should be noted that the size of plastic landslides is small - tens of meters along the length and front edge, rarely the first hundreds of meters. The size of the structural-plastic landslide is 100 × 500 m. The size of the landslide is 80 × 60 m, the lithological composition of the rock is sandy-clay, the sandy part is significantly waterlogged and the slope is steep. 13º. All landslides have in common the presence of debris – debris sliding on bedrock. The nature of the bedrock is largely uncertain due to the lack of outcrops. Only in some cases can it be said that the bedrock is Neogene salty clay of the Vorotyshche Formation. Landslides occur on slopes 40 to 500 meters long and 10 to 20 degrees steep. Depending on the shape of the frontal landslide, the aspect ratio can be 3 or cirque 20. The plastic shear aspect ratio ranges from 0.2 to 5. In terms of landslide volume, most of the plastic landslides were 17 large (over 1000 m^3) and 4 medium (hundreds to 1000 m^3), with only one structure having a smaller plastic volume (about 200 cubic metres). In terms of the depth of rock affected by shear deformation, all landslides are shallow, plastic – from 0.3 to 2.5 m, landslides – 2.8 m, and structural-plastic – 5 m. This is determined by the height of the fault wall (0.3 to 5 m). The slope of all the walls of the sinkhole is almost vertical. According to the slope orientation, the landslide is mainly south-facing and the body of the slope is mainly south-west facing. The sliding surface is flat or slightly cylindrical. The landslide belongs to the Prut River basin.

Table 1

Factors of activation of EGP (natural component) [Kasiyanchuk, 2016]

Group of factors	Factor	Characteristics of its effect on the process	Factor characteristics
Geological	Lithofacial type of underlying rocks	Determines the ability of rocks to hold together	The coefficient of the lithofacial zone, geological formation
	Engineering and geological region	Characterises: - climate and soils; - character of the relief; - geological structure; - nature of rocks; - hydrogeological conditions; - current physical and geological processes	Coefficient of exposure within the district (including other EGPs)
Meteorological	Precipitation	Characterises the ability of soils to moisten	Amount (intensity) of precipitation
Tectonic	Tectonic faults	Determine erosion activity, groundwater level and relief energy	Distance to tectonic fault
Geomorphological	Erosion basin	Characterises changes in hydrodynamic pressure	Distance to erosion basin
	Elevation	Determines the type and composition of rocks, determines micro-geoclimatics	Absolute elevation
	Slope steepness	Determines the stressed state of the slope	The angle of inclination of the daytime surface
	Nearest surface manifestation of EGP	A potential source of slope stress increase	Distance to the nearest manifestation
	Watershed	Determines hydrological flow conditions	Distance to watershed
	Slope direction		Slope exposure

According to water level observations in the well, its depth does not exceed 1-2 m. However, during the dry season, before the landslide activates, the water depth in some wells reaches several metres and even exceeds 10 metres. Landslides are usually wet. Some leaks are observed.

Based on the developed methodology [Kasiyanchuk, 2016], a map of environmental and geological risk assessment for the territory of the Ivano-Frankivsk region was created [Kasiyanchuk, et al., 2016].

Analysing the landslide hazard risk map (Fig. 2) for the Kosiv district of the Ivano-Frankivsk region, there is a clear correlation between the spatial distribution of landslides and the areas most vulnerable to their activation.

The overall risk for the study area varies from 35.2 to 72.1 percent, which is quite high. However, this is confirmed by both the complex hydrogeological conditions and the results of the field studies. Given the content of the methodology described above, risk should be understood as a complex that describes the probability of landslide development and activation based on changes in natural conditions. The dynamics of global climate change is currently the dominant component of landslide triggering factors.

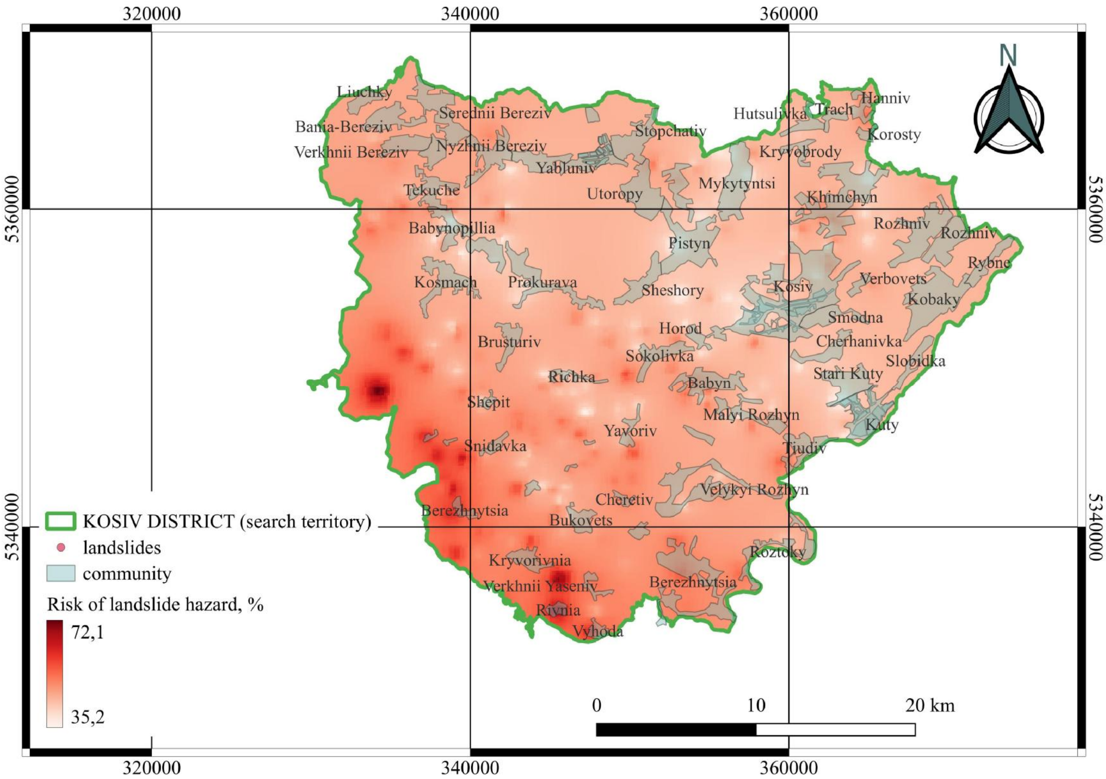

Fig. 2. Landslide risk map of Kosiv district

The central, southern and south-western parts of the district are more prone to landslide development, mainly due to the overlap of factors such as precipitation, altitude, exposure, slope angle and groundwater level, which create ideal conditions for the activation of gravity processes.

The southern and south-western parts of the study area are characterised by a high risk, which is determined by the factors of absolute height, precipitation, and slope angle, i.e. the transition of the region's territory to mountainous.

It is worth noting that the territory of Kosiv district is heavily dotted with rivers, which cause landslides, especially in the Cheremosh River basin. This is due to significant slopes of river banks and rocks that are subject to mass transfer due to groundwater reaching the surface and the formation of a zone of rock decompaction.

An important factor of significant risk for the study area is the resettlement of the population, which ultimately formed the sustainable ethnological, economic and social structure of the area. Construction in difficult geological conditions poses significant risks to human activity, especially in the context of climate change and precipitation, which is the trigger for landslide formation.

The possibility of using the State Land Cadastre data as a source of interoperable data greatly facilitates the study of certain parameters, including those that may have a significant impact on the type of land use.

Data analysis using a geoinformation approach makes it possible to assess the landslide hazard in any given area.

According to the State Land Cadastre and the Kadastr.Live plugin using the QGIS environment, 65,538 land plots with a total area of 26,969 ha were allocated within the study area. Considering that the study area is 877.2 km^2, the cadastral data cover about 30% of the territory, which is mainly the area of settlements.

Structurally, cadastral zones are divided into 8 types: 1) residential and public development land; 2) recreational land; 3) industrial, transport, communication, energy, defence and other purposes; 4) nature reserve and other environmental protection lands; 5) recreational land; 6) forestry land; 7) water fund land; 8) agricultural land. Table 2 shows the general characteristics of the cadastral plots of Kosiv district within each type of land according to their purpose.

Table 2

General characteristics of cadastral plots in Kosiv district

№	Type of designation	Number of plots, pcs.	Total area, ha (according to the SLC)	Total area, km^2	Share of the area within the study area, %
1	Residential and public development land (1)	30073	5297	52.97	6.04
2	Recreational land (2)	141	196.98	1.97	0.22
3	Industrial, transport, communications, energy, defence and other purposes (3)	553	331.17	3.31	0.38
4	Lands of nature reserves and other environmental protection purposes (4)	48	4925.82	49.26	5.62
5	lands for health improvement purposes (5)	11	39.02	0,39	0,04
6	Forestry lands (6)	78	4590.45	45.90	5.23
7	Water fund lands (7)	18	96.12	0.96	0.11
8	Agricultural land (8)	34616	11492.02	114.92	13.10
	Total	65538	26968.6	269.7	30.74

In the total share of 30.74% of the areas for which the type of designation is determined, the largest areas are occupied by forest land – 5.23%, land of the nature reserve and other environmental protection designation, residential and public development land - 5.62%, residential and public development land - 6.04% and agricultural land – 13.10%. As can be seen from Table 2, the share of land used by the population for living and working is more than 62% of all land with a cadastral number, followed by land under protection, including forests – about 35%. Presentation of all types of land according to their intended use in the cadastre

The next stage of the study is to assess the risk of landslides within each cadastral number using geostatistical analysis methods.

Table 3 presents the results of the statistical analysis of the landslide hazard assessment calculated based on the geoinformation approach with the construction of a map for individual cadastral plots within Kosiv district (Fig. 3).

Landslide hazard, the map of which is shown in Figure 2, presents us with data in the form of pixels, each of which has a corresponding value. When constructing the landslide hazard assessment map for the area of Kosiv district, the concept of zonal statistics was used, i.e. the values of raster pixels were estimated for polygons of the cadastral parcel layer. This approach most accurately describes areas of large area or elongated shape.

It should be understood that relief shapes are crucial for the formation of gravity processes. Therefore, the presentation of statistical characteristics such as average risk value, minimum, maximum and standard deviation allows a clear assessment not only of the landslide risk value itself, but also of the spatial change for a particular cadastral parcel.

As can be seen from the map (Fig. 3), the distribution of risk within a given settlement is heterogeneous and depends on the factors that trigger landslides (Table 1). The risk value varies from 35.2 to 67.1% and characterises the area as prone to landslides due to the complex hydrogeological, climatic and landscape conditions. This spatial extent is confirmed by the corresponding statistical analysis, where the standard deviation varies from 0.1 to 0.6%, characterising the data as well as describing the risk value by evaluating the pixel values of the landslide hazard map of the Kosiv district.

Fig. 4 shows the histograms of the distributions of the mean landslide hazard values for individual land use types.

It can be clearly seen that the probability for each type is in the range of 42-48%.

Table 3

Statistical characteristics of landslide hazard data variability

	Variability of average values				Variability standard deviation				Variability of minimum values				Variability of of maximum values			
	Mean	Min	Max	Std.Dev	Mean	Min	Max	Std.Dev	Mean	Min	Max	Std.Dev	Mean	Min	Max	Std.Dev
(1)	44/4	35.2	61.2	2.7	0.1	0.0	3.8	0.2	44.3	35.2	61.2	2.8	44.5	35.2	61.2	2.7
(2)	47.3	41.1	56.6	3.8	0.2	0.0	1.6	0.4	47.0	40.9	56.6	3.5	47.5	42.2	56.6	4.0
(3)	44.8	38.7	55.3	2.2	0.1	0.0	2.5	0.3	44.6	38.7	55.3	2.2	44.9	38.7	55.5	2.3
(4)	45.2	43.1	54.3	1.6	0.2	0.0	1.1	0.3	44.8	40.5	54.3	2.0	45.7	44.0	54.3	1.7
(5)	43.4	40.4	45.2	1.5	0.1	0.0	0.4	0.2	43.2	39.7	45.2	1.8	43.5	40.9	45.3	1.4
(6)	49.5	44.0	57.6	2.3	0.6	0.0	4.6	0.8	48.7	44.0	54.7	2.1	50.9	44.1	70.2	3.8
(7)	45.6	43.3	50.6	1.9	0.2	0.0	1.1	0.4	45.4	43.2	48.7	1.4	45.7	43.4	51.1	2.1
(8)	45.1	35.2	65.2	2.7	0.1	0.0	3.6	0.2	45.0	35.2	64.4	2.7	45.3	35.2	66.1	2.7

Fig. 3. Landslide hazard assessment map for selected cadastral plots within Kosiv district

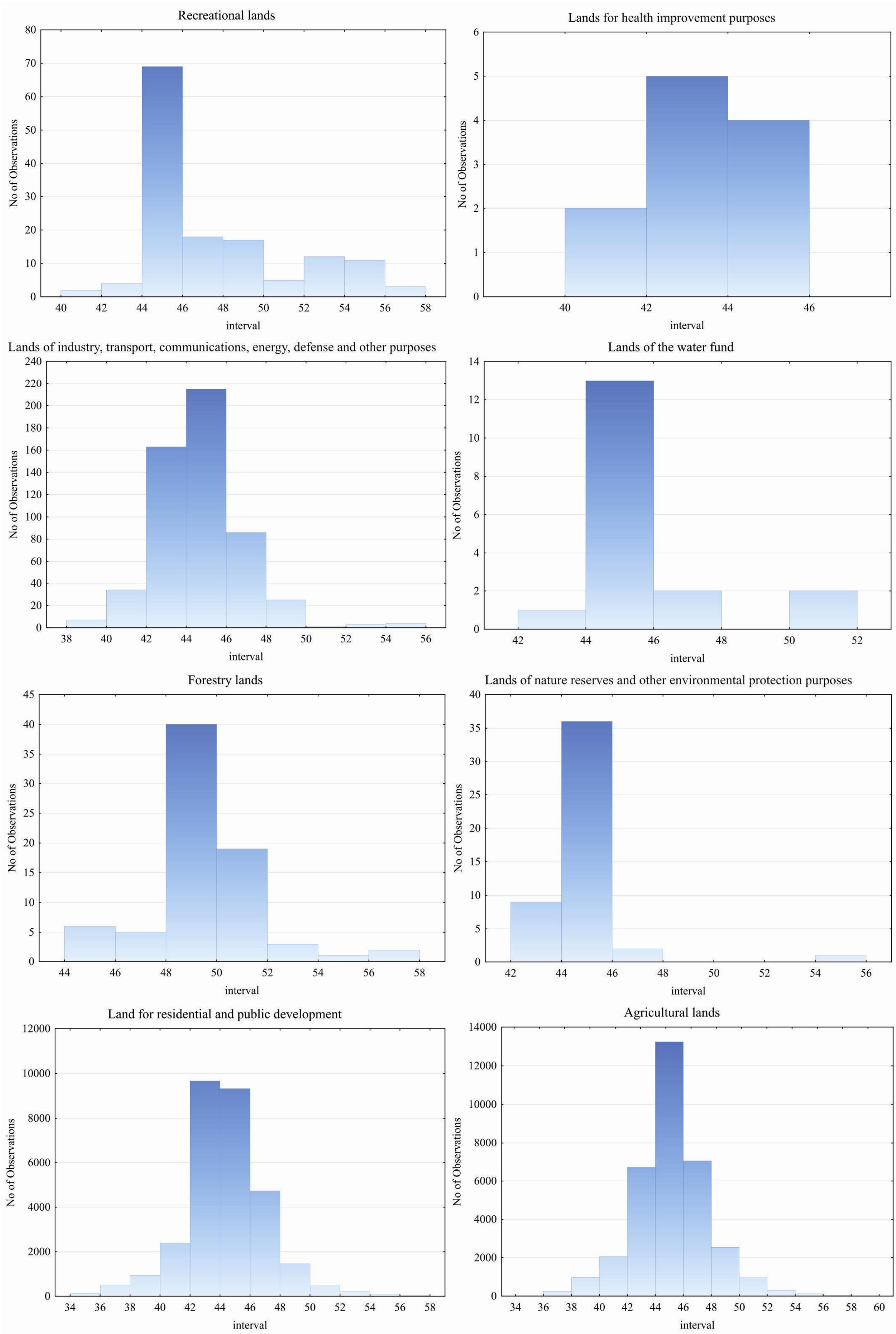

Fig. 4. Histograms of the distribution of average landslide risk values

In particular
- recreational land - 44-46%;
- lands for health improvement purposes - 42-44%;
- industrial, transport, communications, energy, defence and other purposes - 44-46%;
- water fund lands - 44-46%;
- forestry lands - 48-50%;
- lands of nature reserves and other environmental protection purposes - 44-46%;
- residential and public development land - 42-44%;
- agricultural land - 44-46%.

It should be noted that the areas with active economic activity are distributed according to a normal law, while the areas of nature reserves and other environmental protection purposes are distributed according to a lognormal law. This irregularity in the frequency of the distribution can be explained by the fact that the former ise characterised by a high density within homogeneous natural conditions, while the latter is characterised by the heterogeneity of the impact of factor characteristics, especially geomorphological ones, as evidenced by the spatial distribution of landslides in Kosiv district.

Scientific novelty

For the first time, an analysis of the natural component of landslide hazard risks was conducted for the territory of Kosiv district as a basis for the assessment of such risks for individual cadastral zones. The risk analysis was formed on the example of certain areas as a basis for clarifying the regulatory and monetary assessment and for changing the intended purpose of the land or for carrying out economic activities that require hydrogeological research.

Practical significance

Application of the methodology of division into natural and anthropogenic components of landslide hazard risk assessment factors, which allows the identification of areas within the study area where the probability of landslide development and activation is highest when natural factor characteristics are studied.

Conclusions

Based on the results of the research, it should be noted that

1) the reason for the formation of new landslides or the aggravation of existing ones is the geological structure of the slopes, which allows the formation of a sliding mirror and the main deformation horizon; significant heights and angles of the slopes; extreme amounts of precipitation; anthropogenic factors - cutting and loading of the slopes;

2) the use of zonal statistics of pixel values for polygons of the cadastral parcel layer allowed the landslide hazard risk to be assessed for individual areas;

3) the assessment of the probability of landslide hazard risk of cadastral plots varies from 35.2 to 67.1%, and the value of 44-46% is the most frequently repeated;

4) when making decisions at the regional level to reduce the negative environmental impact of landslides, it is necessary to consider predictions of possible occurrence and risk of propagation;

5) The modelling of landslide hazard within individual areas based on cadastral data allows to clearly structure the territory according to the probability of development of gravitational processes under the influence of the natural component of factors.

To effectively identify areas in the existing cadastre that are most exposed to landslide risk, an integrated approach is necessary. This approach should take into account not only the natural factors but also the anthropogenic component of the factors and consider all common types of EGPs. This, in turn, will serve as the basis for a clear delineation of the hazard zones, and the valuation of the land plots and changing their economic purpose will be determined according to the contribution of the cadastral number risk to the development of the EGP, including the temporal component.

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ОЦІНКА РИЗИКІВ ЗСУВНОЇ НЕБЕЗПЕКИ НА ПРИКЛАДІ КАДАСТРУ ЗЕМЕЛЬНИХ ДІЛЯНОК КОСІВСЬКОГО РАЙОНУ

Метою досліджень, які висвітлені у цій статті, є аналіз зсувної небезпеки через оцінку впливу природної складової факторів на землекористування у межах Косівського району Івано-Франківської області. Зростання кількості негативних наслідків від розвитку зсувних процесів у межах території дослідження, та у Карпатському регіоні України зокрема, потребує створення нових підходів в оцінці земельних ресурсів та формуванні цивільного будівництва, з метою зменшення негативних наслідків зсувів на довкілля та людську діяльність. Методика. Дослідження зсувних процесів виконувалося з використанням геофізичних методів, з прив'язкою GPS, геостатистичних методів аналізу даних. На основі сформованого картографічного шару кадастру земельних ділянок і карти ризиків зсувної небезпеки для Косівського району виконаний векторний аналіз з оцінки ризику в кожній ділянці відповідно до його кадастрового номеру. Результати. З допомогою засобів геоінформаційного та геостатистичного аналізу з використанням QGIS виконано розрахунок еколого-геологічного ризику природної складової факторів зсувної небезпеки. Важливим результатом досліджень є побудова карт ризиків зсувної небезпеки земельних ділянок на основі даних Державного земельного кадастру, з використанням плагіну Kadastr.Live Toolbar. Наукова новизна. Вперше виконано аналіз природної складової ризиків зсувної небезпеки для території Косівського району, як основи для оцінки таких ризиків для окремих кадастрових зон. Виконаний аналіз ризиків на прикладі окремих територій, як основу для уточнення нормативно-грошової оцінки та зміни цільового призначення земель чи ведення господарської діяльності, що потребує гідрогеологічного довивчення. Практична значущість. Використання методології розподілу на природну та техногенну складові факторів оцінки ризиків зсувної небезпеки, що дозволяє виділити в межах території дослідження зони, де ймовірність розвитку і активізації зсувів є найвищою при дослідженні природних факторних характеристик.

Ключові слова: зсув, кадастр, земельні ділянки, ризик.

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