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MONITORING OF LANDSLIDE-PRONE AREAS USING RADAR DATA: A CASE STUDY OF THE RIGHT LOESS PLATEAU OF THE DNIPRO RIVER (UKRAINE)

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Abstract. The right bank of the Kaniv Reservoir, which belongs to the Right Loess Plateau of the Dnipro River in Ukraine, is highly susceptible to landslides due to the geological features combined with climate change and human activities. Most landslides related complex morphostructure with central, characteristic elements was formed: a loess plateau with unstable slopes; the right-bank valley of the Dnipro River with erosive and accumulative terraces; ridge-beam, erosion and sliding. Human activities, namely clay mining, construction, and the expansion of agricultural lands induce landslides by altering slope stability. The current research aimed to assess landslide hazards by applying the DInSAR methodology, including the influence of slope, lithology, precipitation, and temperature regime. Optical sensors have known limitations due to their inability to capture Earth's surface. The alternatives are radar sensors capable of seeing through the clouds and working independently of daylight. Integrating DInSAR technique data with classical geomorphological research helped define the kinematics and evolution of the landslides and establish their triggering factors in the Right Loess Plateau of the Dnipro River. Using measures in a seasonal change of temperature fluctuation and precipitation quantity can detect the outcrop, not overgrown vegetation areas, illustrating that radar data can detect landslide-prone areas.

Keywords: landslide hazard, DInSAR, land vertical displacement, remote sensing data, geomorphological analysis, slope stability.

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1. Introduction

The landslide processes are a significant geological hazard and often lead to destruction and damage in Ukraine. The main landslide-triggering factors are precipitation, temperature regime of the territory, lithology and geomorphology (Jesus et al., 2017; Bohush-Zadnipryana & Lyashenko, 2023). Globally averaged combine land and ocean temperature show a warming reached approximately 1 °C (likely between 0.8 °C and 1.2 °C) above pre-industrial levels in 2017, increasing at 0.2 °C (likely between 0.1 °C and 0.3 °C) per decade (Allen et al., 2018; Hong et al., 2006). For Ukraine a sufficient amount of solar irradiance and year-round rainfall, highly concentrated during the summer months. Rainfall is highly varied depending upon Ukraine and seasonal variation patterns. Ukraine's climate have been changing in unison with global processes (Khodorovskyi et al., 2023). Due to climate changes against the background of rising average annual temperatures and changes in the precipitation spatial distribution, the frequency of extremely high temperatures in the east of Central Europe including Ukraine is increasing, and the frequency of extreme cold is decreasing. The above processes lead to the intensification of landslides in the Right Loess Plateau of the Dnipro River. In the context of the traditional approaches, the potential landslides are identified based upon field surveys of geomorphologic evidence and in situ observations. Previous researches in Ukraine find out that 80 percent of the territory of Ukraine consist on loess soil that is unstable soil type (Fileccia et al., 2014; Łanczont et al., 2022; Gerasimenko, 2006; Hlavatskyi & Bakhmutov, 2020; Wei et al., 2024). An increasing of water content leads to intensification landslide prone-areas. Due to the combination of joints and layers with the topography, dip slopes are extremely conducive to the occurrence of landslides. Water migration is important triggering factor for landslides. Moreover, water migration can be divided into multiple types such as amount precipitation and reservoir water storage.

Remote sensing data and geological survey materials are applied for active landslides monitoring (Burshtynska et al., 2023; Rasporenko & Liashenko, 2023). Remote geo-ecological monitoring of landslide activation (Yan et al., 2023) includes satellite optical and radar data. The investigation and interpretation of the patterns of movement associated with landslides have been undertaken using a wide range of techniques, including the use of survey markers, extensometers, inclinometers, analog and digital photogrammetry, both terrestrial and aerial, and synthetic aperture radar interferometry (InSAR). These techniques have allowed substantial improvements in understanding landslide movement patterns in recent years (Petley et al., 2005). Photogrammetry and InSAR (Bauer-Marschallinger et al., 2019; Ivanik et al., 2020), on the other hand, can provide excellent spatial coverage but are generally limited in terms of temporal resolution, meaning that large movement events are rarely captured in detail using these techniques. The DInSAR (Differential Interferometric Synthetic Aperture Radar) technology, including mitigating the non-displacement noise components, was used in our study, especially for the study area. Satellite orbital vector error, phase unwrapping error, and atmospheric delay noise (Xu et al., 2023) within DInSAR data were minimized, leading to InSAR-derived surface deformation's accuracy. Remote sensing technologies have been widely used for landslide investigations in Ukraine. The focus is on landslide prone-area identification, monitoring, and meearly warning.

The presented study aims to monitor and assess landslide hazard regions affected by climate vulnerability at the local scale. This article delves into the details of the research conducted in the Right Loess Plateau, providing insights into applying radar data for landslide hazard monitoring. By elucidating the complex relationship between geological factors, human activities, and climate influences, the study aims to contribute valuable knowledge for the region's effective landslide risk management and mitigation strategies (Kril & Shekhunova, 2019).

1.1. Study area

Compared to traditional methods of landslide research, satellite data gives an advantage, consisting of the remote accessibility of the object, visibility for conducting observations, and the possibility of monitoring geological processes with high periodicity.

Landslides in the Right Loess Plateau of the Dnipro River are significantly distributed their total number is 815 units. They occupy an area of 23.75 km^2, and the affected area of the region is 0.08% within the area of Ukraine. Landslide-prone areas within territorial communities create an additional burden on the management and decision-making system (Orlenko et al., 2023). The change of functional land use, the development of settlements and the safety of community life depends on the availability of information about the distribution of landslide-prone areas, their activation and the forecasting of the state of the territory.

The prerequisites for active vertical shifts are the structure of the slopes and geological conditions. Simultaneously, the triggering factor is long periods of extreme precipitation, fluctuations in the level of groundwater and the level of the Dnipro River. Landslides in the studied area are associated with hydrophilic brown or variegated clays, the overwetting of which causes the activation of landslides.

The landslides examined in the Rzhyshchiv city territorial community (Figure 1) have different characteristics and development stages. The magnitude of landslide development increases in conditions of steepness and height of slopes, fluctuation of reservoir level, and close location to sub-parallel large faults.

Numerous ravines and slopes characterize the

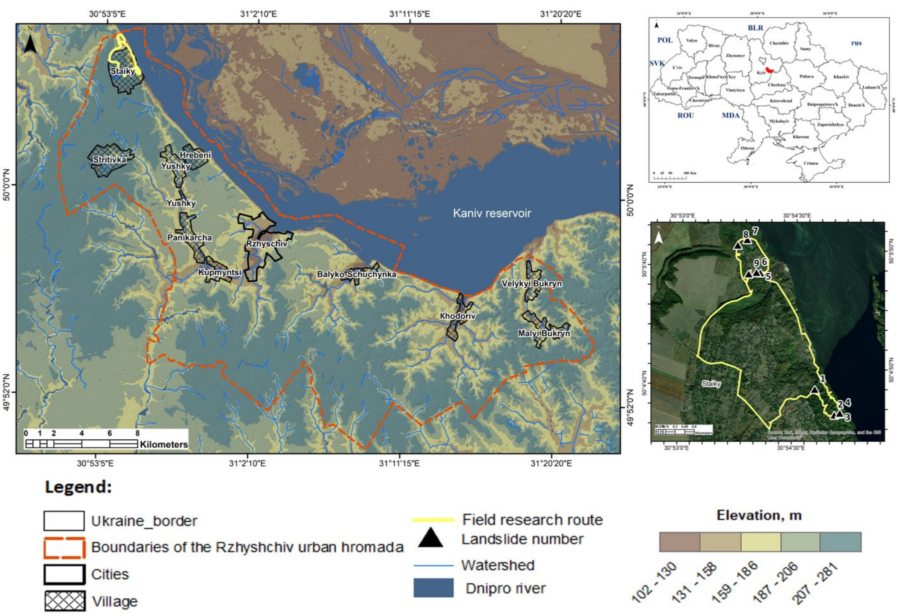

Figure 1. Study area, relief and landslide-prone points, hill-shaded map showing the location of landslides

landscape around Rzhyshchiv. The settlements are located in the valleys of deep ravines, which leads to a complex configuration of the settlements, their distribution into separate masses and complex terrain. The hydrometeorological factor is defined as one of the primary triggers of landslides.

In particular, the increased activity of landslides in 2013 was produced by excessive precipitation and oversaturation of the soil cover with moisture. Vegetation, especially trees, covers a significant part of the right bank of the Kaniv Reservoir, making the stabilized landslide bodies visually invisible on optical images. Vertical walls of landslides with outcrops can be observed only from lower terraces or floodplains.

The quarries development region, which significantly impacts the study area, includes numerous marl extraction pits of the Kyiv Paleogene world (Łanczont et al., 2022). Landslides in the study area occur due to the increase in the steepness of the slopes, the violation of the conditions for the natural flow of groundwater from the deposits of the Quaternary, Neogene, and Oligocene ages, the deprivation of the slope of its rigid base.

Southern slopes within the study area have dense vegetation cover and are less prone to displacements. Quarrying is absent here, and the coastal slope has a forest cover. In its lower part, stabilized landslides of the structural type provide further protection. The central mass of active landslides is confined to depressed areas of landslides and has a block-flow character. In the south-eastern part of the site, landslides are activated only due to manufactured causes such as artificial irrigation on summer cottages.

1.2. Remote sensing data

The advantages of remote sensing techniques of researching the Earth's surface compared to traditional ones are the survey scale, the possibility of obtaining global and local information about objects, and the monitoring of geological processes in real-time. Sentinel-1 is a European Space Agency (ESA) satellite mission that uses a Synthetic Aperture Radar (SAR) system to collect data (Ardha et al., 2021; Blasco et al., 2019). DInSAR is a remote sensing technique that measures and monitors vertical topography displacements associated with landslides (Hussain et al., 2022; Yeşilmaden et al., 2021). Detection of changes in the radar signal phase is evidence of the movement of objects on the Earth's surface. Analysis of radar data with a certain periodicity allows us to establish the dynamics of these changes.

1.3. Climate data

The study region is located in a temperate continental climate zone, where climatic conditions play a significant role in the development of gravitational processes. The less stable the slope, the more likely a landslide will develop. At the same time, in geologically stable territories, the risk of landslides increases due to the gradual impact of climate changes, such as the slow reduction of vegetation cover or the destruction of rocks.

The soil stability and the potential susceptibility of the studied area to landslides are directly influenced by climatic conditions, particularly the amount of atmospheric precipitation and temperature. For instance, a prolonged period of atmospheric precipitation leads to the oversaturation of slopes with moisture, increasing the weight of the soil cover and reducing its strength. The uneven distribution of atmospheric precipitation further heightens the vulnerability of the soil cover, especially when there is a difference in humidity between the upper and deeper layers of the soil. High air temperature has a significant impact on the soil, leading to the drying of clay soils and cracking of sandy surfaces. This process reduces the number of soil particles and leads to the accumulation of silt. As the temperature increases, the soil expands, altering its internal structure and increasing stress in the soil massif, which is a major cause of landslides.

1.4. Field surveys

The studied region has a two-tiered geological structure. The lower geological layer is represented by complexly dislocated and intensely metamorphosed Neoarchean-Proterozoic formations of the crystalline basement, mainly granites of the Uman complex. The depth of the crystalline basement in the described area does not exceed 260–280 m. The upper geological layer consists of sedimentary deposits of the Meso-Cenozoic cover – Triassic, Jurassic, Cretaceous, Paleogene, and Quaternary systems. Middle Paleogene deposits of the Kyiv suite are widespread throughout the study area and are absent only in the Dnipro River valley because they are washed out (Lishchenko et al., 2017). They are represented by three lithological horizons: submarly sands, marls, and non-calcareous sandy clays. The marl-clay stratum is one of the main deforming horizons in developing landslides within the study area on the lower slopes. Its roof is a sliding surface for masses of over-moistened rocks above. The absolute mark of the roof of the plateau is 110–115 m, and within the sliding slopes, 85–110 m. The thickness of marl-clay deposits reaches 30–35 m.

Landslide processes are intensified due to anthropogenic influences, such as clay mining in quarries. The studied territory is divided by a high-powered ravine system. Landslides and erosion-denudation phenomena complicate most of the Dnieper slopes, and they have a wavy upper edge. Given these conditions, further analysis is needed to assess the impacts and stability of the area. Nine tests and five control sites were selected to determine vertical displacements. Landslides and erosion affecting the slopes' topography are observed in all test points. Some places are naturally stabilized due to dense vegetation.

- Test site one is a wooded site with shallow upper soil ooze and erosion in the loam structure. The depth of the cut is about 8 m.

- Test site two is an active landslide point, a potential hazard that requires immediate attention. A fresh detachment wall in the middle part of the slope, the exposure of which is recorded in the lower Pleistocene layer and Miocene sands. The separation wall is up to 7 m, and the width of the landslide section is up to 20 m.
- Test site three, characterized by a small shear site in the form of a flow, has undergone natural stabilization. The upper part of the landslide area still preserves the detachment wall. Still, the diluvial deposits are already overgrown with bushes and trees under five years old, providing a natural barrier against further instability.
- Test site four is a slight shift in the ridge part of the slope between two erosion depressions on both sides. The wall of the gap can be traced; it is up to four meters high. Below it lies a diluvial shelf of loam with a hilly surface partially overgrown with bushes.
- Test site five is characterized by a large outcrop of soil mass at the bottom of the slope above a former marl pit filled with water. The open area's dimensions reach 30 m.
- Test site six has a highly dissected slope due to the quarry's undercutting, characterized by interspersed ridge-like landforms.
- Test site seven is an active landslide; the lower part of the body is overlain by colluvial-diluvial material constantly moving due to collapse, erosion, and displacement.
- Test site eight has a frontal shift representing the upper part of the slope of the studied area, the loess loam in the detachment wall has a columnar structure, and the outcrop is recorded on Middle and Upper Pleistocene sediments.
- The landslide of the detachment wall at test site nine is formed by ridge-like columnar relicts of loess loam at the top of a highly weathered and eroded slope.

Five reference sites located on the watershed levelled surfaces of the loess plateau without woody vegetation, on grey podzolized soils but with a low perennial herbaceous cover, and situated under fallows.

They are overgrown with wild plants, mainly grass-herbaceous associations, representing ruder coenoses. These sites remain uncultivated for extended tens of years. It is believed that the fluctuation of the hypsometric level of the surface within these areas does not exceed 3 mm.

2. Methodology

In the study of the risk of landslides in the territory of the Rzhyshchiv United Territorial Community, a general methodological scheme is used (Figure 2), which is based on the integration of radar, geological, and meteorological data obtained by remote sensing and the results of field research.

The first stage consists of comprehensive data collection, subject to further processing and analysis. Among them are geological survey data and climate data.

The next step is utilizing differential radar interferometry to process radar satellite images. In particular, from 2015 to 2023, during the spring period from March to May, characterized by significant precipitation and temperature fluctuations, special attention is paid to the landslide activation. Radar interferometry aims to study the distribution and magnitude of vertical displacements in the studied region.

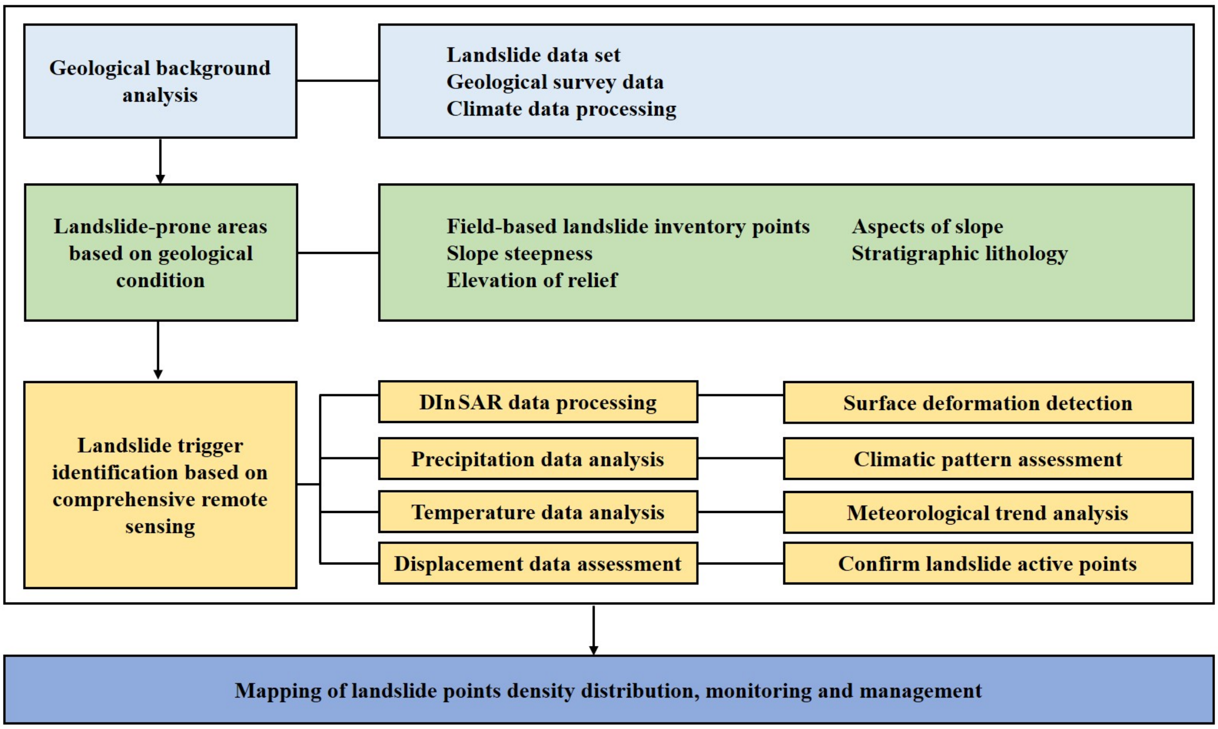

Figure 2. Flowchart of methodology research

GIS project was created in the ArcGIS Pro, which includes maps of vertical displacements, slope steepness map, and also takes into account the amount of precipitation and temperature distribution in the study area. To confirm the obtained data, the elevation of relief data, aspects of slope mapping, and the results of field studies are used, including measurements of the distances from the banks of reservoirs, as well as maps of the distribution of landslides in the territory of the community.

The obtained results make it possible to understand the influence of the increase in precipitation on the formation of landslide processes and to build a mapping scheme of their distribution in the studied territory. This will contribute to developing effective risk management measures and ensuring the population's safety in landslide danger conditions.

2.1. DInSAR data processing

We use remote geoecological monitoring of landslides techniques in the territory of the Rzhyshchiv United Territorial Community. For this purpose data provided by Sentinel-1 satellites on the coverage of the Earth's surface are used. Twenty-three pairs of radar images from 2015–2023, including the spring period from March to May were processed. This period was chosen due to the low afforestation of the studied area, in contrast to the summer period, since a large amount of vegetation is a significant obstacle to obtaining reliable results of the mapping scheme of vertical displacements (Orlenko, 2023a).

In the initial stage, the Sentinel-1 satellite has a 12-day temporal baseline, descending geometry short. The subswath IW3 covers our study area, and these data have a resolution of 10 m. After thorough image correction and formation of the initial interferogram, we applied the Goldstein method to filter the data for noise reduction. We then proceeded with phase unwrapping and conversion of values into physical quantities, taking into account the masking of areas of low coherence, primarily the surface of the reservoir in our study.

The next step is to select areas with zero displacement to correct the obtained results geometrically. The final stage was creating a mapping scheme of vertical displacements of the earth's surface and determining the magnitude of displacements at each point of the studied territory and in field research areas (Orlenko, 2023b).

2.2. Climate data processing

In this paper, the ERA5 climate reanalysis dataset and MODIS data are processed to extract and further model the essential climate variables for the study of landslide activity.

The estimated climate data is compared and validated with accurate ground measurements from different sources (Martazinova & Shchehlov, 2018; Fedoniuk et al., 2023).

Daily precipitation data from March 3 to April 31, during 2015–2023, were selected for the research. It is explained by the fact that the most active periods of the development of landslides on the territory of the Kaniv Reservoir are the autumn and spring periods. MODIS satellite data were used to estimate the temperature indicators of the studied area. The GEE (Google Earth Engine) cloud service obtains temperature values from the MODIS climate data library. The next step was to calculate the average value for each twelve-day interval since the estimate of the amount of precipitation had to be correlated with the flight schedule of the Sentinel-1 satellite for a more accurate determination of the dimensions of the vertical displacements of the Earth's surface. Then, the temperature and precipitation amount rates were estimated for the study area. Then, the landslide active points map provided with the temperature and precipitation measurements related in graphs is presented.

3. Results

Meteorological conditions will change in response to climate change (Intergovernmental Panel on Climate Change, 2014), with different and contrasting effects on landslide hazards. On the territory of Ukraine, increased precipitation total, rainfall intensity, and increase in air temperature lead to aggravated erosion processes and reduction in rock mass strength that create prerequisites for the formation of landslides.

A large amount of water flowing down the slopes can also wash away the soil and create cavities, contributing to the formation of landslides. Snow melting in the winter-spring period and spring and summer rains are factors in the activation of landslides, especially on the banks of reservoirs. Precipitation data levels (Figure 3) are obtained from the ECMWF climate data library using the GEE cloud service, showing the high precipitation level in the spring period over the research region.

Sharp changes in the temperature regime in the spring trigger the activation of landslide processes, especially on the banks of reservoirs, where a large amount of melted snow water leads to landslide intensification. Increasing levels of groundwater and overwetting of the central clay deforming horizons and in places where a thick layer of

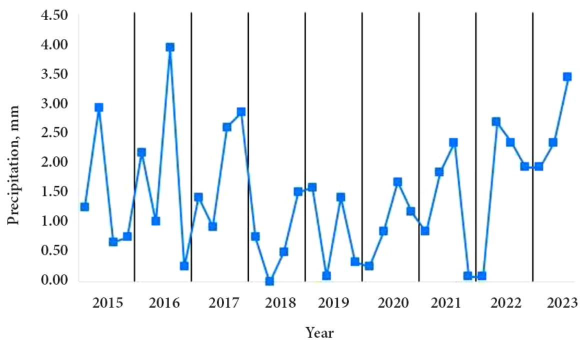

Figure 3. The schedule of distribution of precipitation for the spring period (March–April) by years of the study according to ECMWF data

loess rocks is spread – to their subsidence, intensity which, in turn, depends on the subsidence properties of the deposits of the loess formation in the Right Loess Plateau of the Dnipro River.

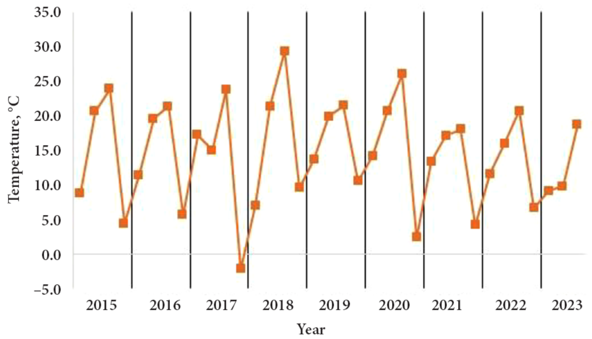

Figure 4. The schedule of distribution of temperature for the spring period (March–April) by years of the study according to MODIS data

Changes in air temperature in the spring period from 2015 to 2023 were analyzed, shown in Figure 4. Results of temperature analysis demonstrated potential susceptibility slope stability responses to changes, including reduced infiltration rate, reduction in shear strength, and rapid snowmelt.

Within the study area, through the analysis of the geological environment and climate conditions, we determined that the Rzhyshchiv United Territorial Community is a landslide-prone area (Figure 5) with a complex geological structure and high landslide density and characterized by straight interdependence with the intensity of precipitation and fluctuation of surface temperature.

According to Figure 5, test sites numbered 5–9 are active landslides. Site numbers 1 and 4 are partially active; areas 2 and 3 are inactive. Intensification of landslides under numbers 5–9 is associated with the influence of climate and anthropogenic factors.

Due to the graphs of the magnitude of the vertical displacements of the sections, Figures 6 and 7, it can be concluded that the constant movement and the presence of vertical displacements of sections numbered 6–9. Site one is characterized by periodic activity in 2015, 2019–2021, and no fluctuations in 2016–2018 and 2022–2023. No vertical displacements were recorded in the site 2–3 during the entire study period. Sites 4 and 5 show little activity in 2016, 2019–2020, 2023. The maximum displacement value of 10 cm was recorded in sites 6 and 9.

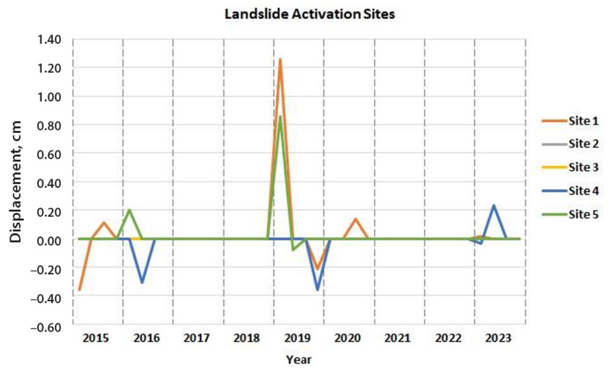

Figure 6. Non-active displacement sites

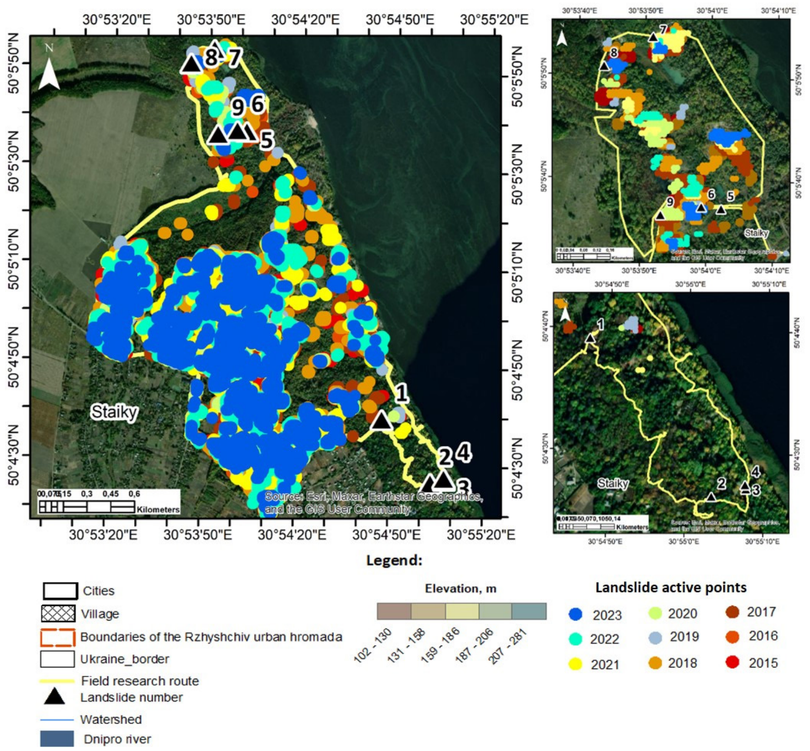

Figure 5. Active displacement points

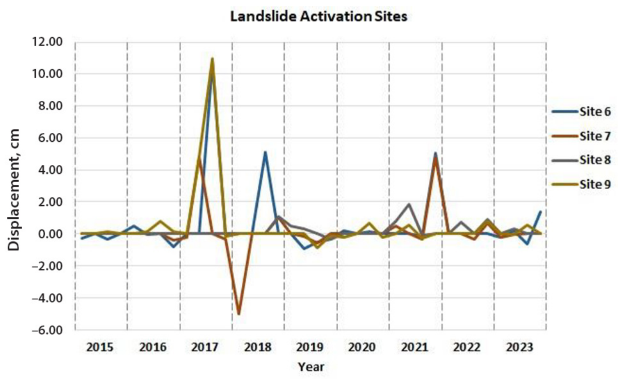

Figure 7. Active displacement sites

The stabilization of 2–4 sites is due to the fixes of the slopes with a large amount of woody vegetation, which acts as a deterrent factor. The analysis results indicate a critical influence of climate factors on the dynamics of landslides in the Right Loess Plateau of the Dnipro River.

At the test sites, most deformation rates observed between 2015 and 2023 in the spring range from 1 to 15 cm per year. A positive displacement value indicates that the surface has moved up or away from the satellite's scanning swath. In the context of our study on shear processes, a positive displacement suggests that the shear body is being pushed up, which is one of the potential causes of the signal phase change. On the other hand, a negative displacement value signifies that the surface has moved down or closer to the satellite's scanning swath. In the case of landslides, a negative displacement indicates soil subsidence, which can be observed as material sliding down or compaction (Orlenko, 2023b).

After obtaining the result of vertical displacement measurements, we get a rasterization of the received data for landslide activity measurement; the output is a continuous raster surface where each cell represents the density of landslide points. The ArcGIS Spatial Analyst Tool Extract values to points have allowed the analysis to be performed, counting the number of events for all the raster layers classes. We extracted the cell values of a raster based on a set of point features and recorded the values in the attribute table of an output feature class. The next step was to select the layer containing landslide points. In the density analysis, we took known quantities of landslide phenomenon. It spreads across the landscape based on the amount measured at each location and the spatial relationship of the locations of the measured quantities. We used point density, which utilizes a kernel density estimation algorithm with a 10 m radius to calculate the density of points within a neighborhood around each cell in a raster grid 10 m^2 in size. Higher density values indicate areas with a higher concentration of landslides (Figure 8).

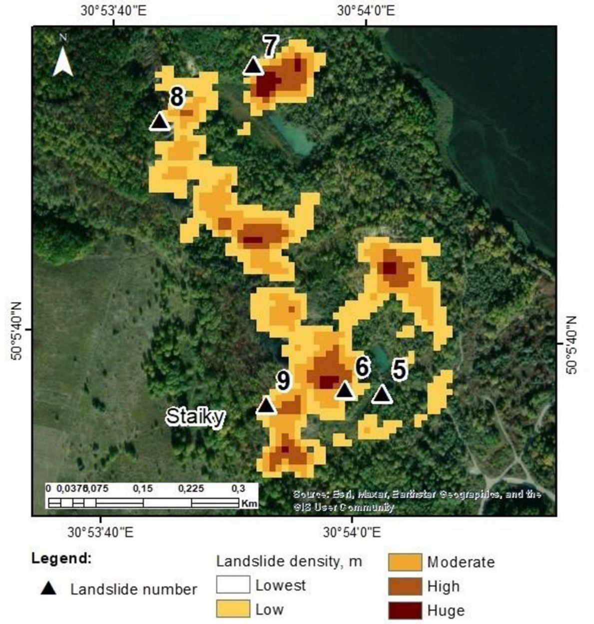

Figure 8. Landslide points density

Therefore, the typical sites with high landslide density are number 6–9, where vertical displacements of the earth's surface have been recorded. Sites 1–3 and 5 are inactive during fieldwork, and when creating a mapping scheme on the territory of site 4, there are recorded displacements that require detailed analysis. The obtained density map shows the level of danger in landslide-prone

Table 1. Amount of landslide site activity from 2015 to 2023

Site number	Year									Amount of movements
	2015	2016	2017	2018	2019	2020	2021	2022	2023	
Site 1	2				2	1			1	6
Site 2										0
Site 3										0
Site 4					1				2	3
Site 5					2					2
Site 6	2	3	2	1	3	2	2		4	19
Site 7			3	2	3		3	2	2	15
Site 8				1	3		3	2	1	10
Site 9	1	3	4		2	3	2	1	2	18

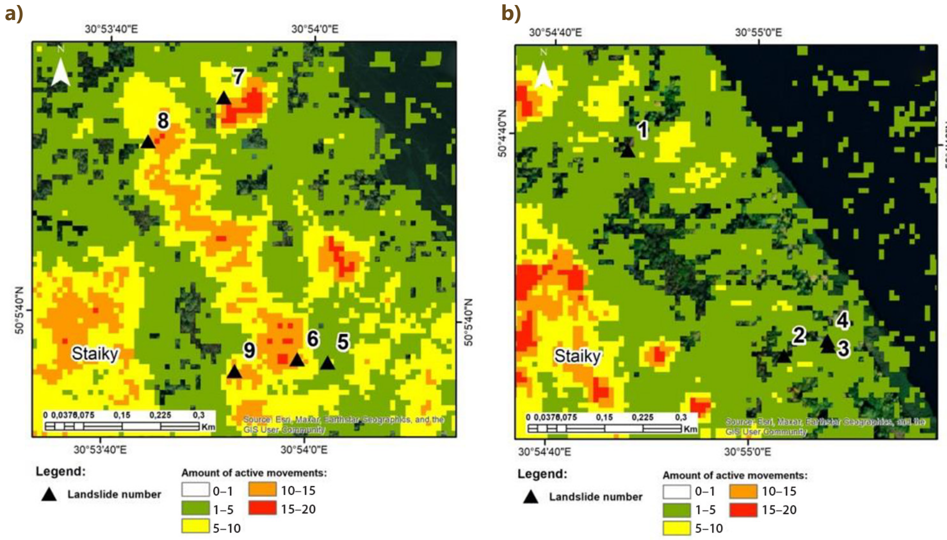

Figure 9. Results map of the amount of activity of landslide processes during 2015–2023

areas. The greater the density values, the more a potential landslide may occur.

Within the period of March to April from 2015 to 2023, the results obtained from the Sentinel satellite data were calculated with a 12-day periodicity; the total number of measurements was 36. The presence of motion at each survey point was analyzed for each measurement result. The number of movements at each end was counted, and the total number of these movements was also determined. The obtained data were systematically entered into a table for further analysis (Table 1).

The results are shown in Table 1 and Figure 9 for the Rzhyshchiv United Territorial Community landslides, reflecting the number of repeated movements recorded during nine years in each studied site during the spring period of increased precipitation and sharp temperature changes.

We created a resulting map (Figures 9a and 9b) illustrating the presence of ground surface motion at each specific test point and its periodicity based on the received radar interferometry data.

For the first, we converted the numerical values of the displacements to binary format (0 or 1) to record the presence of motion at each pixel for each measurement from the 2015 to 2023 study years.

A sum count for each point in the image is performed using the sum function to obtain the total number of movements at each point during the specified period.

For the second step, classification of the received frequency distribution of displacements in each pixel was done using the decision tree method. This method displays the highest motion frequency in red and the lowest in green.

The resulting map illustrates the distribution of the intensity of motion on the Earth's surface, where red indicates high motion activity, and green indicates low motion.

4. Discussion with interpretation of results obtained

DInSAR methodology helps detect landslides that have slipped or have significant deformation in highly vegetation-covered areas. The vegetation cover makes potential and slightly deformed landslides challenging to identify. The results cannot be used directly. Therefore, comprehensive judgment is applicable by analysing regional geological and climate conditions.

The cartographic data analysis results regarding the number of displacements at each point confirmed earlier conclusions regarding the territorial distribution of displacements. It was found that experimental areas with numbers 5–9 have the highest landslide activity, while regions with numbers 1–4 have low or no activity at all, which makes them safer.

As a result of comparing data on the planar and temporal distribution of landslides obtained from SAR for nine years, climatic data confirmed that the activation of landslide processes occurs with a slight delay after intense precipitation exceeding 600 mm per year, especially in 2016.

The maximum density and repeatability of pixels with high excesses were manifested at observation sites 5–9, the slopes in the northeastern village (Figures 10–11). Under the same weather conditions, no observations were made at observation points (Figures 10–11) 1–4 (slopes of the southern part of the studied area).

This is explained by the fact that the first section (Figure 8) has the highest density and periodicity of displacements associated with landslides due to the increase in the steepness of the slopes as a result of the development of marl and clay quarries, the violation of the conditions of the natural flow of groundwater from Quaternary, Neogene and Oligocene sediments, stripping the slope of its rigid base – rocks of the marl stratum, increasing the area of stones subject to weathering.

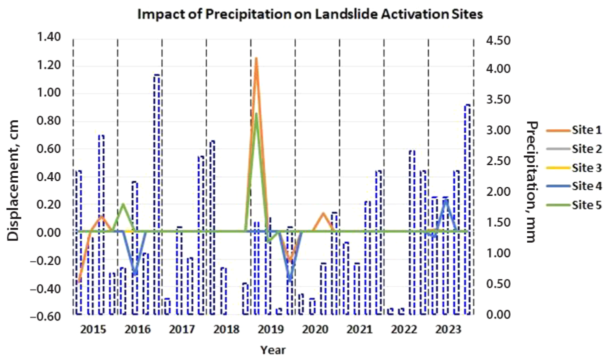

Figure 10. Non-active displacement sites intensified by precipitation

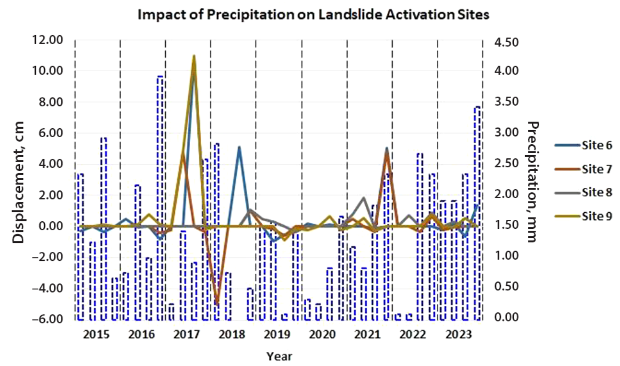

Figure 11. Active displacement sites intensified by precipitation

The destruction of the slope occurs in the form of structural landslides sliding on brown and variegated clays, as well as plastic displacements of the slope deluvium along saddles in the thickness of sands of the Poltava and Kharkiv series.

The slopes south of the village, known as the stacks (Figure 9b), are less susceptible to destruction. This is due to several factors, including the cessation of quarrying of the marl-clay layer for brick production, the terraced nature of the coastal slope, the widespread woodland, and the presence of stabilized structural-type landslides on siltstones and clays of the Paleogene Obukhov world in its lower part. These factors have led to less intensive wetting and percolation into the geological layers, reducing the risk of landslide activation.

Therefore, activation occurs only on open areas of unstable slopes, which have an unformed profile and are prone to landslides during periods of intensification of precipitation. Using an analytical approach based on cartographic data, conclusions about the relationship between landslide activity, vegetation, and climate and geological factors can be drawn.

5. Conclusions

This study proposed an integrated methodology of landslide identification for highly vegetation-covered areas. The methodology included the fixation of the landslide-prone regions based on geological analysis and climate factors that influence utilizing remote sensing data.

Taking the Right Loess Plateau of the Dnipro River as an example, the potential landslides represented by the Rzhyshchiv city territorial community were identified. The north part of the research region has a significant density of potential landslide processes.

A significant advantage of using remote sensing data with a mathematical apparatus for processing many criteria to obtain a result is visibility and flatness. When planning and establishing engineering-geological studies, as a rule, attention is paid to areas already known with a particular history of observations. During the planar assessment of the territory, it is possible to assess those areas where previous studies were not conducted. Still, according to the data of remote geoecological monitoring, there is a high or very high level of danger, and prior studies have yet to reveal such facts, or these areas were not studied.

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