LANDSLIDE SUSCEPTIBILITY MAPPING USING ANALYTICAL HIERARCHY PROCESS AND GEOGRAPHICAL INFORMATION SYSTEM IN RUDNY ALTAI REGION, EAST KAZAKHSTAN

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ABSTRACT:

Landslides are one of the important natural threats that often cause loss of life and property in Kazakhstan. One of the regions affected by landslides of different types and sizes that occur for different reasons in the country is the Rudny Altay Region in the east of Kazakhstan. This study deals with the landslide susceptibility assessment using remote sensing methods in Rudny Altai region of East Kazakhstan. The landslide inventory map was created based on historical information, remote sensing images, and field surveys. Images of 4 selected sites (Tikhaya, Berezovka, Manat and Chernovaya) were examined to determine potential landslide susceptibility. In combined Analytical Hierarchy Process method and GIS (AHP-GIS) used in this study, values are assigned to the selected indicators (layers) from low to high landslide susceptibility potential (1-5). Thus, to assess the potential of landslide processes, the following indicators were selected: calculated values of surface slope according to the NASADEM digital elevation model, soil density, average monthly precipitation OpenLandMap, and median values of the normalized difference vegetation index (NDVI). As a result, the data were obtained and maps of landslide susceptibility of the study areas were created. According to the research results, the highest coefficient of damage to the area by landslide processes is noted in Tikhaya, and the lowest - in Manat. On average, the coefficient of landslide damage in the Rudny Altai area is 0.03, which is a low indicator for this region. The results obtained with the study showed that about 25% of the study area had moderate to high landslide susceptibility. Accordingly, landslide susceptibility is high in the southwest and south of the study area, especially in mountainous areas where slopes are steep and in sloping areas in the south. It was revealed that the results obtained in this study are quite successful in determining the landslide susceptibility of the study area. The findings of the study can contribute in the effective management of the Rudny Altai Region.

Key-words: *AHP, Landslides, Susceptibility mapping, GIS, East Kazakhstan*

1. INTRODUCTION

Landslides are one of the natural disasters that cause loss of life and property. These are mostly seen in sloping mountainous areas. Precipitation, heavy rainfall, slope, ground water, vegetation and human activities are among the factors that trigger landslides (Bayandinova et al., 2018). If the areas that are likely to be landslides are known in advance, the damages of this disaster can be prevented. In general, the forecast of the potential landslide occurrence is indicated by the landslide susceptibility map.

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Information about landslide susceptibility can be presented well and clearly if it is collected properly and mapped correctly (Ayalew and Yamagishi, 2005; Mezughi et al., 2012). The accuracy of the landslide susceptibility map depends on the scale, the number and quality of the data, and the choice of appropriate method in analysis and modeling (Intarawichian and Dasananda 2010). Landslide assessment and susceptibility maps, recognized for their relative spatial predictive capacity of the probability of landslide occurrence, are important tools for landslide prevention and management (Zhu et al., 2023).

In mapping landslide susceptibility analysis, the historical correlation between the factors controlling landslides and the distribution of landslides is important (Guzzetti et al. 1999). It is possible to map landslide susceptibility by applying several methods (Aditian et al., 2018; Chen et al., 2017; Dai et al., 2023; Kumar and Anbalagan, 2016). There are several scientific studies on the prediction, prevention and detection of landslide areas and the creation of landslide susceptibility maps (Zhu et al., 2023; Zhang et al., 2023; Tesfa, 2022; Shan and Ye, 1998; Senouci et al., 2021; Dai et al., 2023; Althuwaynee et al., 2016).

One of the most effective and preferred qualitative methods used for landslide susceptibility assessment is the Analytical Hierarchy Process (AHP) method. This method is used not only for landslide susceptibility but also in other areas (Achour et al., 2017; Afzal et al., 2022; Strokova, 2022; Zhu et al., 2023; Khan et al., 2019; Intarawichian and Dasananda, 2010; Komac, 2006). AHP became a very useful tool in the fields of environmental science and management particularly in planning, decision making, and hazard mapping. Many landslide susceptibility studies were conducted using this tool (Mezughi et al., 2012; Moradi et al., 2012). Some experts have also tried comparing AHP with other popular techniques in decision making such as multiple regression approach in landslide hazard zonation. Likewise, Hepdeniz (2020) used frequency ratio methods in landslide susceptibility mapping in Isparta-Antalya, southern Turkey. Some studies used adaptive neuro-fuzzy inference systems (Chen, 2017) and single machine learning models (Meena et al. 2022; Ngo et al., 2021). Zhang (2023) and Zhu (2023) used landslide susceptibility evaluation integrating weight of evidence model and InSAR results (Shan and Ye,1998; Zhang et al., 2023).

The AHP method is a very suitable approach in the analysis of landslide susceptibility because it includes a multi-criteria decision-making process. Looking at the literature, it is seen that many researchers use different versions of the AHP approach for landslide susceptibility analysis (Rosi et al., 2023; Xu et al., 2023). This study presents a susceptibility analysis of the Rudny Altai region in East Kazakhstan using GIS-based AHP method, considering the hazard and susceptibility factors. In East Kazakhstan, there are frequent cases of the occurrence of such dangerous processes as collapses, screes and landslides, which require additional research in order to prevent a threat to human life, damage to agriculture and infrastructure, the environment and the economy. Landslides can lead to fatal and destructive consequences and significant economic impacts for people living in mountainous areas.

2. STUDY AREA

The East Kazakhstan region is located in the easternmost part of Kazakhstan near the border of Russia and China. The study area is located in the territories of the Tikhaya, Berezovka, Chernovaya and Manat River basins in the Rudny Altai region of East Kazakhstan (**Fig. 1 and Fig. 2**). The relief of Rudny Altai is very diverse, both geologically and geomorphologically (Chekalin, 2002; Dzhanaleeva, 2020; Khasanov, 2021). The eastern parts are deeply incised by rivers and the terrain has become a dissected. In the east of the region, the elevation increases and the terrain becomes more rugged. A typical upland Kazakh steppe, where the forms of low hills and elongated ridges alternate with flat spaces and wide river valleys, replaces the intermontane plains. Towards the west, the elevation decreases, the topography becomes more flattened and plateaus occupy a large place in this part (Zhanabayev et al., 2023). The relief amplitude varies from 145 to 4500 meters above sea level (Belukha Mountain). Thus, we can presumably divide the territory of East Kazakhstan into 3 zones, each characterized by its own relief features.

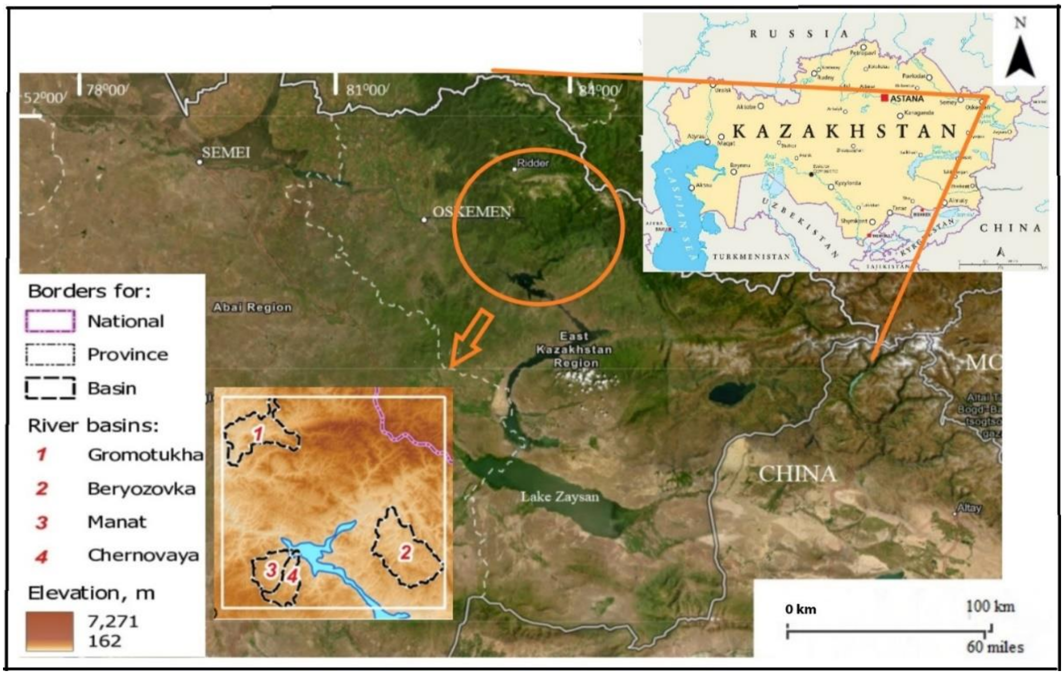

Fig. 1. The territory of East Kazakhstan Province.

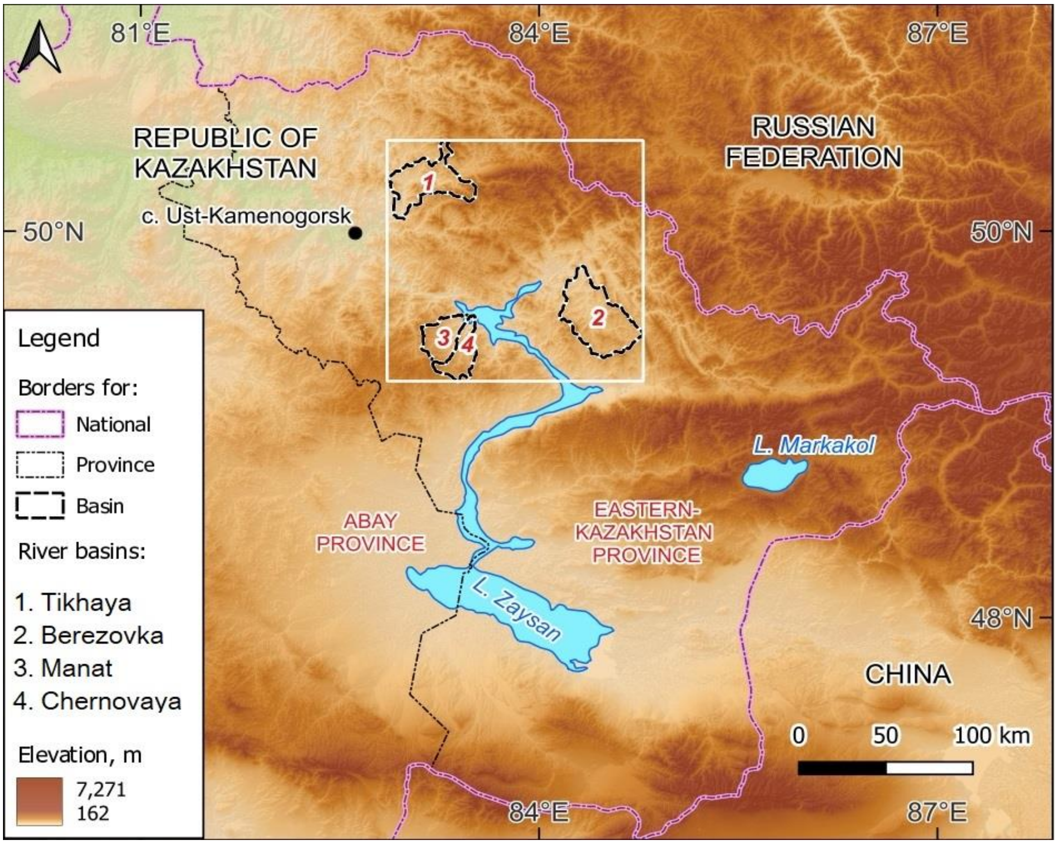

Fig. 2. Location map of the study area.

These are the Irtysh plain in the northwest, a small hillock an intermediate strip, and a high-mountainous region that closes them from the northeast, east, and southeast. including several sections with watersheds of 150-200 m relative height. The latter one is the subject of the study, where researched areas are located.

The Gorny Altai region in the north of Central Asia is a place where natural disasters such as landslides, especially landslides, and stone falls are frequent (Deev et al., 2023; Buslov, 2013). The site varies greatly in geographical features. In the region, climate, vegetation and soil characteristics show distinct zones in the vertical direction.

There are large steppe areas to the north spreading in northwest of the region and gradually moving towards the south-east and east into the area of high mountain ranges. The climate of the region is sharply continental with large daily and annual amplitudes of air temperature fluctuations. Winters are harsh, summers are relatively long and hot. The territory of the region receives a fairly good amount of precipitation, not counting its southern part. 400-600 mm of precipitation falls in the foothills and mountains per year, and on the western slopes of Altai mountains in some years - more than 1600 mm. The waters of the site are drained by the Irtysh River and its tributaries. The Rudny Altai region is one of the regions with the highest susceptibility to landslides in Kazakhstan due to its topographical, and climatic features.

3. MATERIAL AND METHODS

AHP is one of the decision-making methods that has a wide range of applications in many areas such as regional planning, land use, environmental impact assessment, and takes into account many criteria. AHP, introduced by Saaty (1980), is a flexible approach that can be adapted to many different multi-criteria decision-making problems. In recent years, it has been widely used in the generation of landslide prediction and landslide susceptibility maps (Saaty, 1980; Saaty, 1987; Thanh and De Smedt, 2011; Mezughi et al., 2012; Moradi et al., 2012). Four key areas were selected according to the geosystem-basin approach (Ramazanova and Dzhanaleeva, 2012). Then, within each of the sites of the study area, research was carried out to analyze the potential susceptibility to landslide. For this purpose, a model for assessing the territory of potential susceptibility to landslide has been compiled. A combined Analytical Hierarchy Processing method (AHP-GIS) was used in this study (Saaty, 1980; Saaty, 1987; Das et al., 2022). This method involves the use of different layers, which are recalculated by the ranking method - assigning values to selected indicators (layers) from low to high landslide susceptibility potential (1-5) (Arulbalaji et al., 2019; Chattaraj et al., 2021). This method was chosen because it is very useful in complex situations that need to be considered. This method is used as an alternative in the analysis of landslide susceptibility from qualitative data or judgments to quantitative data.

In this study, the boundaries of river basins were taken into account in determining landslide areas. The boundaries were determined by the HydroBASINS method. This method includes a series of vectorized polygon layers that show sub-basin boundaries on a global scale (URL 1). The goal of this product is to provide a seamless global coverage of consistently sized and hierarchically nested sub-basins at different scales by a coding scheme that allows for analysis of catchment topology such as up- and downstream connectivity. HydroBASINS was extracted from the gridded HydroSHEDS core layers at 15 arc-second resolutions (URL 1; Lehner and Grill, 2013; Intarawichian and Dasananda, 2010). Using the Analytical Hierarchy Process (AHP) method in the Google Earth Engine geographic information system, actual 9 images from the Landsat-8 spacecraft were analyzed for the period from 2000 to 2022.

The use of geographic information modeling methods to identify landslide susceptibility is a necessary condition for conducting regular observations of modern landslides. Comparison in GIS of the results of interpretation of space images taken in past years allows us to accurately record the changes that have occurred (El Jazouli, et al., 2019).

Based on remote sensing data using geoinformation modeling methods, a digital relief model of the Tikhaya, Berezovka, Chernovaya and Manat River basins and the distributions of the displacement amplitudes of points on the earth's surface for the period 2000-2022 were determined. At the same time, the degree of susceptibility to landslides and the coefficients of distribution of the examined areas were calculated.

Using the method of Analytical Hierarchy Process (AHP) method in the Google Earth Engine geoinformation system, the research gives the results of deciphering imagery and generates maps of the susceptibility to landslides of the studied territories. The used methodology for assessing the landslide susceptibility of the studied areas is shown in the diagram (**Fig. 3**). The produced landslide susceptibility map was classified into four categories as insignificant, low, medium and high susceptibility.

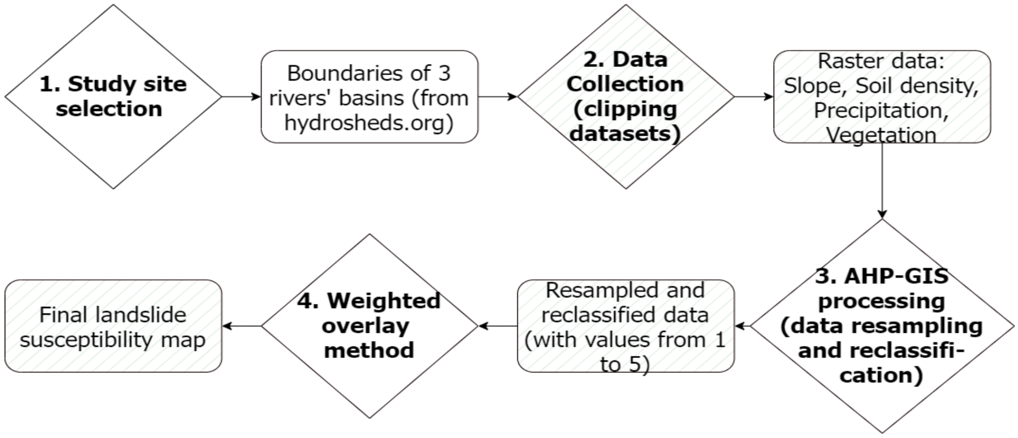

Fig. 3. Scheme of methodology for assessing susceptibility to landslides.

Maps of the degree of susceptibility of the studied sites to landslide were generated using the Analytical Hierarchy (AHM) methodology by decoding satellite images of key sites in the Google Earth Engine geoinformation system. The coefficients of the areal distribution of the studied sites to landslide processes were determined based on images from the Landsat-8 satellite for the period from 2000 to 2022 (Elhag and Bahrawi, 2017; Hengl, 2018; Hengl and Parente, 2022; URL 2).

There are four data employed in this study (**Table 1**). They are

(a) calculated values of the surface slope according to the NASADEM digital elevation model (URL 4). NASADEM Merged DEM Global 1 arc second V001 [Data set]. NASA EOSDIS Land Processes DAAC. (URL 5)

(b) soil density (Hengl, 2018). Soil bulk density (fine earth) 10 x kg / m-cubic at 6 standard depths (0, 10, 30, 60, 100 and 200 cm) at 250 m resolution (Version v02) (Hengl 2018)

(c) the average monthly precipitation from OpenLandMap (Hengl and Parente, 2022)

(d) the median values of the normalized difference vegetation index (NDVI) map generated from Landsat 8 data (Elhag and Bahrawi, 2017).

The obtained recalculated ranked indicator values are subjected to resampling of cell size for convenience in further calculations. These layers were selected as the most informative and available for assessment within the scope of this dissertation. Based on the referenced publications, we assume that the most landslide-prone areas (5 out of 5 points) have high slope, low soil density, high precipitation, and low vegetation coverage. Calculations were performed using the Google Earth Engine online service. Data for basins were analyzed separately, except for the Manat and Chernovaya rivers, where calculations were conducted jointly due to their proximity to each other.

The data for the basins were analyzed separately, except for the Manat and Chernovaya, where the calculations were carried out jointly due to their adjacency to each other.

Table 1.

List of source data selected after AHP-GIS method application.

Index	**Source**	**Cell size, m**	**Period**
Pool boundaries	HydroBASINS	vector layer	2000
Surface slope (%)	NASADEM	thirty	2000
Soil density (kg/cubic m)	OpenLandMap	250	2018
Precipitation (mm)	OpenLandMap	1000	2007-2019
NDVI	Landsat -8	thirty	2013-2022

4. RESULTS AND DISCUSSIONS

Spatial analysis was applied to obtain a landslide susceptibility map of the study area. Applying this function, each variable must have the weight of influence on the occurrence of certain phenomena and the attribute data of each variable divided into value classes. The influence weights of variables were calculated using Analytical Hierarchy Process (AHP) method. The coefficient of the area affected by landslide processes ranges from 0 to 1, with 0-0.15 indicating low impact, 0.15-0.5 indicating medium impact, and 0.5-1 indicating high affected area. The largest coefficient of areal effect by landslide processes is in the Tikhaya, the smallest is in the Manat and Chernovaya. On average, the coefficient of landslide damage in the Rudny Altai territory is 0.03, which is the average for small, local territories, such as the studied areas.

For ranking, the maximum and minimum values of the basins of the selected indicators of the study area were obtained in accordance with **Table 2**. This table shows that generally, the slope steepness values are similar for all 4 sections, which corresponds to the characteristics of the relief with a high degree of dissection. In the basin of the Tikhaya River, zones with a high degree of susceptibility to landslide are located in the southeastern part. This area is located in the Gromotukha River basin (left tributary of the Tikhaya River). The area north of the city of Ridder, which has a high degree of susceptibility to landslides, is located in the Tikhaya River basin.

Zones with a moderate degree of susceptibility to landslide are found on the left slope of Tikhaya River valley, which has a more mountainous terrain and is significantly higher than the right slopes. In the Berezovka, zones with a moderate degree of susceptibility to landslide are located in the mountainous areas in the central and western parts of the basin. In the northern part of the basin, where the degree of susceptibility to landslide is moderate. In the Manat and Chernovaya, zones with a moderate degree of susceptibility to landslide are also located in the mountainous areas in the eastern, southwestern and central parts of the basin.

In order to determine the coefficient of spatial damage of the studied areas to landslide processes, we use the method of Sheko and Lehatinov (1974) according to the following formula:

$$K_p = \frac{f_{p,}}{F} \tag{1}$$

where: K_p – coefficient of areal damage;
f_p – the area affected by landslides;
F – the area of the studied site.

Table 2.

Values selected after ranking.

Location	Surface slope (%)	Slope steepness degree	Soil density (kg/m3)	Precipitation (mm)	NDVI	Ranking coefficient (score)
Tikhaya	11.1	10	162.0	499.0	0.9	1
	22.2	20	143.4	548.0	0.7	2
	33.3	30	124.8	597.0	0.5	3
	44.4	40	106.2	646.0	0.4	4
	55.5	50	87.6	695.0	0.2	5
Berezovka	11.2	10	143.0	413.0	0.9	1
	22.4	20	133.2	446.0	0.7	2
	33.7	30.3	123.4	479.0	0.5	3
	44.9	40.4	113.6	512.0	0.4	4
	56.1	50.5	103.8	545.0	0.2	5
Manat and Chernovaya	10.6	9.5	143.0	404.2	0.9	1
	21.2	19	135.6	428.4	0.7	2
	31.9	28.7	128.2	452.6	0.5	3
	42.5	38.2	120.8	476.8	0.4	4
	53.1	47.8	113.4	501.0	0.2	5

The coefficient of areal damage to landslide varies from 0 to 1, where 0-0.15 is low damage, 0.15-0.5 is medium damage, and 0.5-1 is high damage. In the study, the areas of the obtained raster files were calculated for each area studied, as well as 5-high and 4-moderate landslide-prone areas according to **Table 3**.

Table 3.

Areas of sites prone to landslides (sq. km).

The degree of susceptibility to landslides	Tikhaya	Berezovka	Manat and Chernovaya
F	838.0	1200.0	818.1
f_p with degree 5	*1.0*	*0.2*	*0.1*
f_p with degree 4	*35.0*	*28.2*	*17.3*
Total f_p	36.0	28.4	17.4
OVERALL K_p	**0.043**	**0.024**	**0.021**

When susceptibility classes are examined, it was seen that the highest rate of area damage caused by landslides is in Tikhaya, and the lowest rate is in the Manat and Chernovaya (**Table 4**). On average, the coefficient of landslide damage to the territory of Rudny Altai is 0.03, which is a low indicator for this region.

The areas and rates of the landslide susceptibility classes are given in **Table 4**.

Table 4.

Area of susceptibility classes and area percentage.

Classes	**Tikhaya Area %**	**Berezovka Area %**	**Manat and Chernovaya Area %**
High	0.1	0.02	0.01
Moderate	4.18	2.35	2.19
Medium	53.88	65.6	39.5
Low	28.28	28.13	48.3
Insignificant	13.56	3.9	10
Total	100.00	100.00	100.00

Based on this method, we generated maps of the degree of susceptibility to landslide processes of the studied sites, as well as to determine the coefficients of their involvement in landslide processes. As can be seen from the **Fig. 4**, in the Tikhaya, the areas with the highest degree of steepness of slopes are located in its eastern part and correspond to the maximum values. In the case of the Berezovka, they are in the western part of the basin. In the Manat and Chernovaya, they are located mainly in the central, eastern, and southeastern parts.

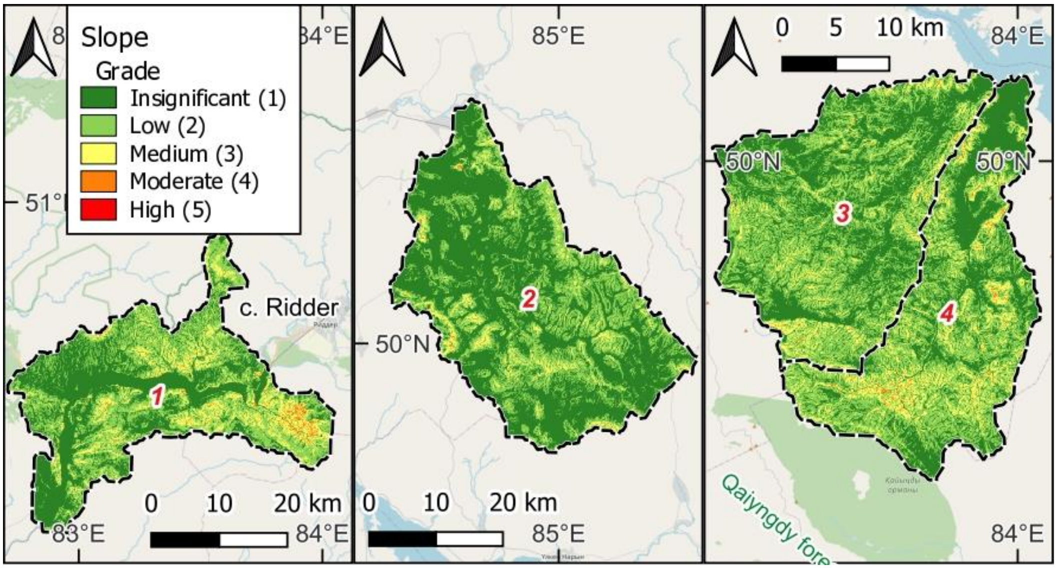

Fig. 4. The degree of steepness of the slopes (Source: Author, created in the Google Earth Engine); The numbers on the map indicate: 1 - Tikhaya, 2 - Berezovka, 3 - Manat, 4 - Chernovaya.

The highest soil density is observed in Tikhaya and the lowest in Berezovka (**Table 3 and Fig. 5**). In Berezovka, more than 50% of the soils are loose in nature. Moderate soil density is observed in most of Manat and Chernovaya.

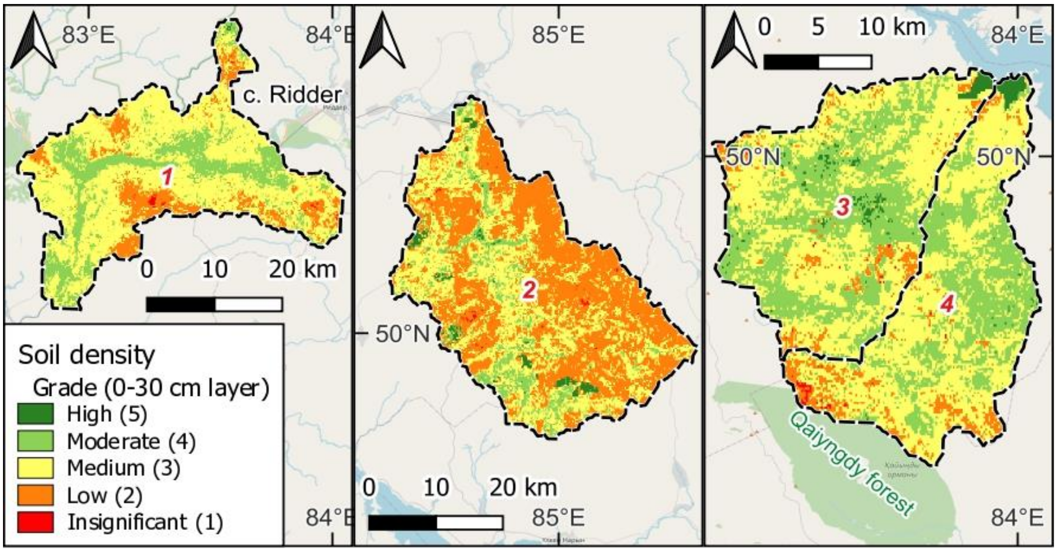

Fig. 5. Degree of soil density (source: Author, created in the Google Earth Engine). The numbers on the map indicate: 1 - Tikhaya, 2 - Berezovka, 3 - Manat, 4 – Chernovaya.

As can be seen from **Table 3**, areas with the maximum amount of precipitation were recorded in the Tikhaya, the average amount in the Berezovka, and the lowest in the Manat and Chernovaya, which is also seen in **Fig. 6**. A pattern can be traced in accordance with the largest amount and high degree of long-term median monthly precipitation in cases with all the considered basins here.

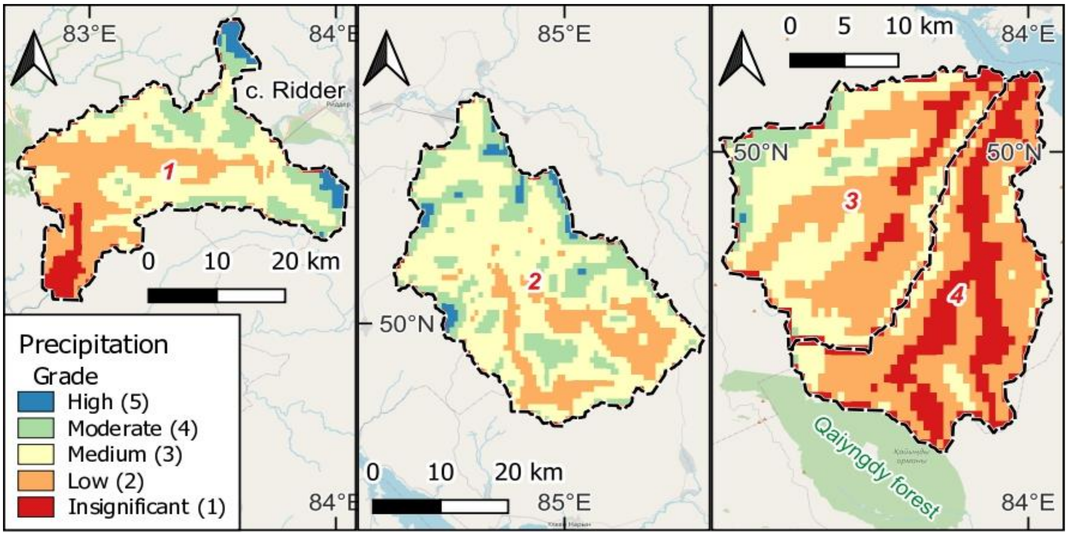

Fig. 6. Amount of precipitation degree. (Source: Author, created in the Google Earth Engine). The numbers on the map indicate: 1 - Tikhaya, 2 - Berezovka, 3 - Manat, 4 – Chernovaya.

Areas with above-average rainfall prevail in Tikhaya and Berezovka, while low rainfall prevails in Manat and Chernovaya. At the same time, areas with the maximum amount of precipitation are in the form of islands in certain areas. According to **Table 3**, vegetation (NDVI) has a similar range of values from 0.2 to 0.9. The densest vegetation occurs in Tikhaya. In Berezovka, vegetation has an average value (**Fig. 7**).

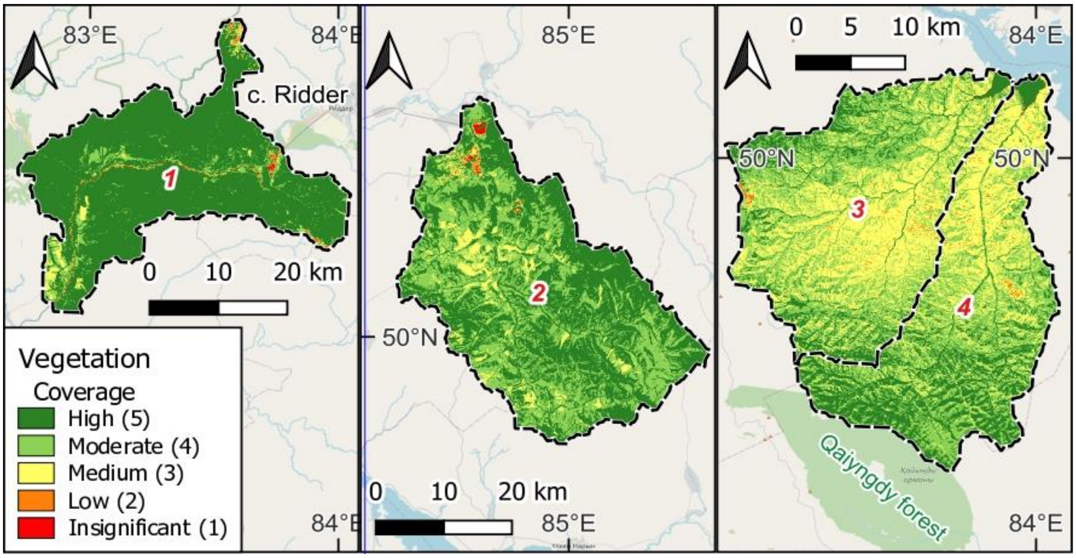

Fig. 7. NDVI grade (source: Author, created in the Google Earth Engine). The numbers on the map indicate: 1 - Tikhaya, 2 - Berezovka, 3 - Manat, 4 – Chernovaya.

In the Manat and Chernovaya, about half of the territory has an average vegetation index. There are also open areas with minimal vegetation, which are likely to be actively affected by human activities. These sites correspond to the location of open-pit mining areas.

Considering the results obtained, the potential susceptibility of the studied areas to landslides was calculated and mapped. As a result, maps of the degree of susceptibility of the Tikhaya, Berezovka, Manat and Chernovaya regions to landslide processes were created. (**Fig. 8**).

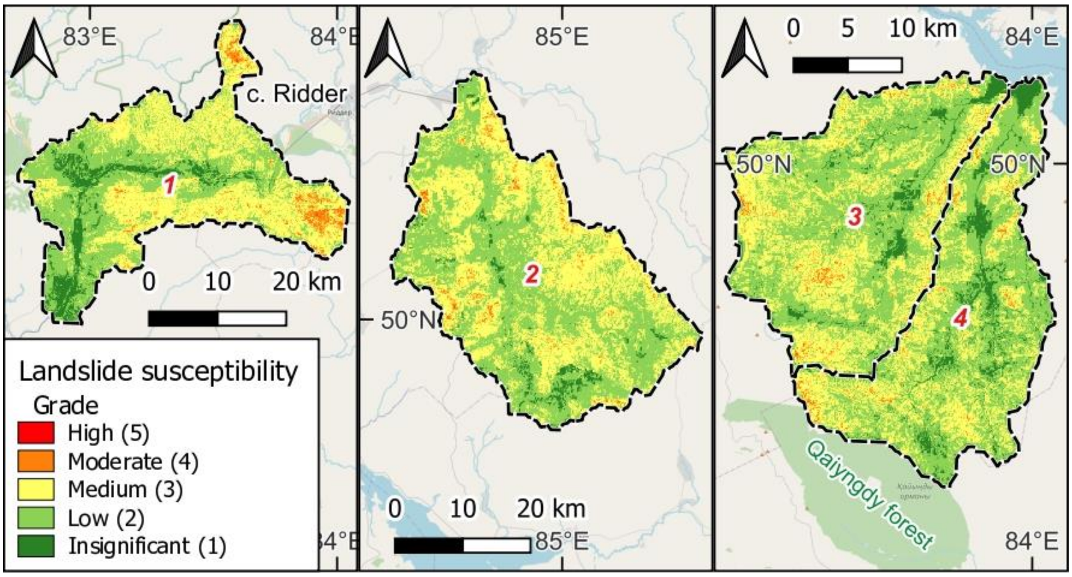

Fig. 8. Map of susceptibility classes (source: Author, created in the Google Earth Engine). The numbers on the map indicate: 1 - Tikhaya, 2 - Berezovka, 3 - Manat, 4 – Chernovaya.

Looking at the data obtained, it is understood that the area most susceptible to landslides (5 points out of 5) have high slope steepness, low soil density, high amount of rainfall and low vegetation. We can see that the areas with the highest and moderate degrees of susceptibility to landslide generally correspond to areas with a low vegetation index, looser soils with the greatest amount of precipitation and a high degree of slope steepness located mainly in the areas of upper parts of watersheds.

In the Tikhaya, zones with a high degree of susceptibility to landslide are located in its southeastern part - the Gromotukha River basin (the left tributary of the Tikhaya River), where the Ridder–Sokolny and Obruchev mines are located. The high susceptibility to landslides in the upper basins of the rivers is related to the high slope steepness, the low vegetation cover and the mining activities (**Table 5**).

Table 5.

List of initial data selected after ranking.

Index	**Source**	**Cell size, m**	**Period**
Basin boundaries	HydroBASINS	Vector layer	2000
Surface slope (%)	NASADEM	30	2000
Soil density (kg/m^3)	OpenLandMap	250	2018
Precipitation (mm)	OpenLandMap	1000	2000-2022
NDVI	Landsat-8	30	2000-2022

The resulting layers after recalculation were summarized using the weighted overlay method, which is the sum of the recalculated values of four selected layers. Weighting factors were assigned for each of the layers used in the following order: 35% for the slope of the surface, 30% for soil density, 20% for precipitation, and 15% for vegetation cover according to equation (Intarawichian and Dasananda, 2010).

$$LSI_b = \sum_{i=1}^{4}(W_i \times R_i) \quad (2)$$

where:

LSI_b is the desired index of landslide susceptibility of R_i pixel in basin b,

W_i is the weight coefficient, and factor weight for factor i (four factors in this study), obtained using the AHP-GIS method.

The values of the weight coefficients of the factors were equated: 0.35 (surface slope), 0.3 (soil density), 0.2 (precipitation), and 0.15 (NDVI). Thus, the values of each of the four indicators for each pixel were multiplied by weights and then summed, obtaining raster layers of landslide susceptibility for each section of the study area.

The final step of the calculation involves re-ranking the obtained landslide susceptibility values to obtain a landslide susceptibility map. The landslide susceptibility mapping produced using AHP methods, which are classified into insignificant, low, medium, moderate and high susceptible zones, is closely related to historical landslide information.

5. CONCLUSIONS

Landslide susceptibility map is prepared using the Analytical Hierarchical Process (AHP) for the Rudny Altai region in eastern Kazakhstan. Five landslide causative factors were analyzed to produce the susceptibility map of the area. The three major influencing factors to induce landslide in the Rudny Altai district are: Surface slope (%), Soil density %, Precipitation (mm)%, NDVI %. Landslides are disasters that cause significant environmental and social problems, especially in mountainous areas. They occur as a result of the combination and interaction of several complex factors such as topography, soil, precipitation and plant cover.

The main objective of this study was to evaluate landslide susceptibility and prepare map in the eastern Kazakhstan area. In this study, literature review, field research and preparation of causal factor maps were applied, respectively. Landslide susceptibility maps prepared from AHP were classified as insignificant, low, medium, moderate and high susceptibility.

The resulting recalculated ranked values of the indicators are subject to resampling the size of the cells for convenience in further calculations. These layers are selected as the most informative and accessible for evaluation within the framework of this research. Based on these publications, we assumed that the areas most prone to landslides (5 points out of 5) have a high slope steepness, low soil density, a high amount of precipitation, and little vegetation cover. The calculations were made using the Google Earth Engine[2] online service. The data for the basins were analyzed separately, except for the Manat and Chernovaya, where the calculations were carried out jointly due to their adjacency to each other.

Maps of the distribution of values of displacement amplitudes (in mm) of points on the Earth's surface for the period 2000-2022 and the degree of susceptibility to landslide of the studied sites are constructed. On average, the coefficient of landslide damage to the territories of the studied sites is 0.03, which is a low degree of damage. Although they occur in sparsely populated areas, landslides still cause great damage to the national economy by disabling roads, irrigation systems for farmland, and drainage, complicating logging and fieldwork. The obtained results of conducted research suggest that on seismically active territories, there are constant shifts in the Earth's surface. When combined with geosystem indicators such as climate, vegetation cover, and surface slope, these shifts activate landslide processes.

Landslides can result in the loss of life and injury to people in hazard zones, destruction of agricultural lands and crops, and potentially even harming animals in the study area. They can damage roads, bridges, buildings, and equipment, and undermine infrastructure, leading to water resource pollution and soil erosion. Only continuous observation and monitoring of landslide processes will allow for their early detection and implementation of necessary measures to prevent the listed risks. Furthermore, landslides can lead to significant economic losses

Landslides cause losses in many places and it is important to identify them in advance to avoid their damages. Landslide susceptibility assessments to be prepared for this purpose have an important function for this purpose. Scientists proposed several methods and models for GIS-based AHP assessment of landslide susceptibility. However, there are few studies on landslide susceptibility assessment for East Kazakhstan. In this paper, the landslide susceptibility mapping of the AHP model using GIS is analyzed.

The results of this study are consistent with the results of landslide susceptibility mapping studies conducted in other areas. Since we conducted the study in a specific area, the results for the whole area will only be available after future studies and can be used as a general data. The findings provide useful information for the prevention and mitigation of landslide risk in the study area. As a result, risk analysis methods should definitely be used to prevent losses caused by landslides.

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