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MORPHOMETRIC ANALYSIS OF THE SATY USING THE GIS-TECHNOLOGIES

The problem of exodynamic processes occurring in the mountain regions of Kazakhstan is particularly acute. These processes that occurred on the territory of the village of Saty in April 2018 demonstrated that they not only pose a threat to tourist routes laid to mountain lakes but also have serious social, economic and environmental consequences for the lives of people and the security of the economic infrastructure. To determine and predict such processes, it is necessary to know the relief features of the studied area and evaluate both its quantitative and qualitative indicators. To determine the morphometric relief parameters using modern GIS technologies and open access sources, the village of Saty was chosen as an object. In the course of the work, ASTER-GEM images with a resolution of 30 m and ArcGIS software were used. As a result of the study, maps of the slope of the terrain and the exposure of the relief were constructed. It was determined that most of the territory belongs to the area with an average steepness (35%) and steep (30%).

The results of the work can be further applied to determine the stability of the slopes to the manifestation of exogenous processes, as well as during landscape zoning and planning in the mountainous regions of the country. Also when assessing environmental risk.

Key words: morphometric analysis, exodynamic processes, GIS, DEM, Kazakhstan, slope, aspect.

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ГАЗ-технологиясы негізінде Саты ауылының морфометриялық талдауы

Қазақстанның таулы өңірлерінде орын алатын экзодинамикалық үдерістердің мәселесі өте өткір. 2018 жылдың сәуір айында Саты кентінің аумағында орын алған бұл үрдістер тау көлдеріне салынған туристік маршруттарға қауіп төндіріп қана қоймай, адамдардың өміріне, сондай-ақ халықтың қауіпсіздігіне елеулі әлеуметтік, экономикалық және экологиялық салдарлары бар екенін көрсетті. Осындай процестерді анықтау және болжау үшін зерттелетін аймақтың рельефтік ерекшеліктерін білу және оның сандық және сапалық көрсеткіштерін бағалау қажет. Қазіргі заманғы ГАЗ технологияларын және ашық қол жеткізу көздерін қолданып, морфометриялық рельеф параметрлерін анықтау үшін, Саты ауылына объект ретінде таңдалынды. Жұмыс барысында ASTER-GEM 30 м рұқсатымен және ArcGIS бағдарламалық жасақтамасы қолданылды. Зерттеу нәтижесінде жер бедерінің карталары және рельефтің әсер етуі туралы карталар жасалды. Белгілі болғандай, аумақтың басым бөлігі орта қарқындылығы (35%) және тік (30%) ауданға жатады.

Жұмыстың нәтижелері экзогендік үрдістердің көрінісіне беткейлердің тұрақтылығын анықтау үшін, сондай-ақ еліміздің таулы аймақтарында ландшафтты аймақтарға бөлу және жоспарлау кезінде қолданылуы мүмкін. Сондай-ақ экологиялық тәуекелді бағалау кезінде.

Түйін сөздер: морфометриялық талдау, экзодинамикалық үдерістер, ГАЗ, ДЕМ, Қазақстан, еңістік, экспозиция.

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Морфометрический анализ села Саты с использованием ГИС-технологий

Проблема экзодинамических процессов, протекающих в горных областях Казахстана, стоит особо остро. Данные процессы, произошедшие на территории села Саты в апреле 2018 года, продемонстрировали, что они не только несут угрозу туристским маршрутам, проложенным до горных озер, но и характеризуются серьезными социально-экономическими и экологическими последствиями для жизни людей и безопасности хозяйственной инфраструктуры. Для определения и прогнозирования таких процессов нужно знать особенности рельефа исследуемого участка и оценить как количественные, так и качественные его показатели. Для определения морфометрических показателей рельефа с помощью современных ГИС-технологий и источников открытого доступа было выбрано объектом село Саты. При выполнении работы использовались снимки ASTER-GEM с разрешением 30 м и программный продукт ArcGIS. В результате исследования были построены карты уклона местности и экспозиции рельефа. Определено, что большая часть территории относится к местности со средней крутизной (35 %) и крутой (30 %).

Результаты работы в дальнейшем могут быть применены для определения устойчивости склонов к проявлению экзогенных процессов, а также при ландшафтном районировании и планировании в горных областях страны. Также, в оценке экологического риска.

Ключевые слова: морфометрический анализ, экзодинамические процессы, ГИС, ЦМР, Казахстан, склон, экспозиция.

Introduction

According to the results of the report “Strategic measures to combat desertification in the Republic of Kazakhstan till 2025” the reduction of glacier area is associated with global warming. These changes entailed a reduction of 30% of the territory of the glaciers on the Tien Shan over the past 60 years. As noted in the report (GEF-UNDP project, 2015), “they are also among the causes of natural disasters, such as landslides, mudflows, and affect the balance of water throughout the Central Asian region”.

It is important to study the quantitative characteristics of the relief for the prevention, investigation, and prediction of these processes that is morphometric analysis. With an easy to use and efficiently designed GIS technologies for morphometric analysis of the relief makes it possible to determine the relationship between the genetic and age characteristics of the relief and its morphometric parameters (Maltsev, 2006), the ability to assess the geomorphological recreational resources of the territory (Antiptseva, et al., 2009) and others. Geographic information system (GIS) depends on computer programs and is used to preserve, restore, monitor and display information (Sabins, 2000) on the location of the sciences of geology, geography, and environment.

The study of some areas is complicated by the fact that they are not available for study depend-

ing on the location (mountainous terrain), climatic conditions and season. In this regard, in the present-day world, the new mapping methods by using GIS technologies and remote sensing techniques of the Earth are actively used to solve this issue. To determine the foci of landslides, mudflows, which took place earlier in the study area, and to predict and prevent these processes, use of available open free source data gives good results. In our case, for obtaining quantitative information about the relief and building thematic maps (terrain slope map, exposure, etc.) were used the data of the digital elevation model (DEM) ASTER GEM with a resolution of 30 m from the USGS website.

The relevance of the work is determined by the fact that so far for the territory of the village of Saty and in general for the Altyn-Emel National Park there are no materials on the quantitative characteristics of the relief and its analysis.

Meanwhile, these studies are extremely necessary to assess the role of the relief in the development of adverse exogenous processes that are actively developing, including in the territory of the mountainous areas of our country (soil and gully erosion, landslide and other processes). As the Committee’s press service (2018) reported, as a result of observing the Kolsay gauging station of the Kazselezaschita CPSU of the Ministry of Internal Affairs of the Republic of Kazakhstan in the Almaty region, there was a shift in the rock mass on April 19, 2018.

A significant amount of precipitation fell out over a short period of time and affected the activation old landslide hearth.

Considering the interest of developing tourism and increasing the flow of tourists in a given area, it becomes necessary to analyze morphometric characteristics and regionalize the relief of Saty village using GIS technologies to predict these processes with the least harm to the local population. To achieve this goal, a comparative analysis was made of the existing DEM and comprehensive morphometric analysis of the relief of the village Saty using GIS technologies.

The results obtained in this work can be applied in various areas of geography, to solve numerous geoecological problems, when calculating potential soil losses, determining the stability of slopes to the manifestation of exogenous processes (EGP), in cal-

culations to determine the arrival of solar radiation on and also in landscape zoning and planning, finally, in environmental risk assessment. The developed technique can be used when building a DEM of any scale.

Materials and research methods

Saty village is a starting point to mountain lake systems like Kolsay. Located in the Kegen district of Almaty region, 283 km from Almaty. In 2018, a large movement of rock mass occurred near the plot lying to the village of Saty, that is, 10 minutes from the place. According to the physical-geographical regionalization of Kazakhstan, the site under consideration belongs to the Tien Shan area, and is located in the ridges dissected by the N-S trend valleys of the Saty River (Vilesov, et al., 2009: 148, 251) (Fig. 1).

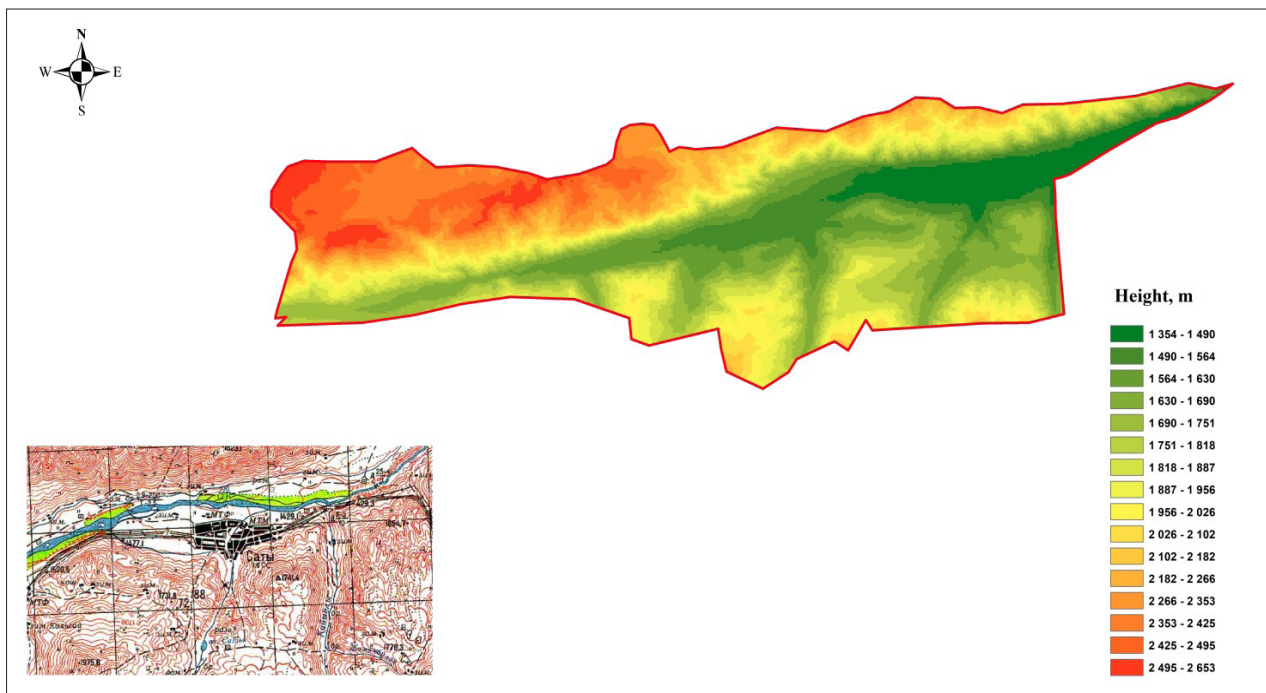


Figure 1 – Hypsometric levels and geographical location of Saty village

When choosing to use data, an analysis was made of existing DEM data, both in terms of quality indicators, accessibility, and territory coverage. As in most of the works performed on morphometric analysis of territories, initial data were used from one of the Shuttle Radar Topography Mission (SRTM) and ASTER GLOBAL DEM data from the USGS, NASA and

METI sites (ASTER GDEM Validation Team, 2011; Belz et al., 2015). Also, using these data, studies were conducted in different regions (Moudrý et al. 2018; Pham et al. 2018; Abboud and Nofal 2017) (Polyakova, et al., 2014), also under different conditions of land cover with vegetation (Mashimbye, De Clercq, and Van Niekerk 2014; Liu et al., 2019; Reddy et al., 2018).

The ASTER GDEM data from the US Geological Survey (USGS) site with a resolution of 30 meters was used as the initial information for obtaining the DEM (Table 1). Also, taking into account the probable measurement error based on the analysis of previously performed works, we chose a scale of 1:50 000 (Saprin, 2015; Narozhna, 2016). Based on the DEM, thematic maps of the most important morphometric parameters were

constructed: a hypsometric map scheme, slope maps and slope exposures (Polyakova et al., 2014). ArcGIS 10.2 software was used to create models and maps, using the Surface and Spatial Analyst tools. To display the legend, standard color gamuts were used: for the hypsometric indicators ranging from light green to dark brown, for the slope map and slope exposure, one color was chosen for each indicator.

Table 1 – General information on the data used in the work

Data	Abbreviation	Spatial Resolutoin	Acquisition Technique	Scale	Measurement error, m	Link
ASTER GDEM	ASTER	1 arc-second	Satellite stereo images	1:50 000	35	https://earthexplorer.usgs.gov/

A qualitative assessment of DEM results must also be confirmed by GPS data. But this is complicated by the fact that many sites are inaccessible for research, they require a lot of time and money. In this regard, the current use of DEM is the optimal method (Kostin, 2011; Liu et al. 2019). For processing digital elevation model (DEM) depending on SRTM data through ESRI, ArcView, ArcGIS and Arc Info products, for determining morphometric parameters, various functions, such as Arc Hydro (Abboud and Nofal 2017), Spatial Analyst (Mikhailov, 2015; Polyakova, et al., 2014) and for the visual assessment of the relief tool Aspect for creating a shadow model of the studied area.

Results and discussion

As a result of using the DEM for thematic maps (hypsometric, slope and slope exposure), it was determined that the average height of the terrain is 1354 m, and the maximum – 2653 m (Fig. 1). Surface tilt angles range from 0 to 36 degrees (Fig. 2a). The average angle of inclination of the surface is 18 degrees, due to the location of the relief (Fig. 2b).

The data obtained as a result of mapping are shown in Table 2.

Due to the fact that the village of Saty is located in a mountainous area, taking into account, the location and indicators of the slope become a necessity for assessing the possibility of determining possible foci of slope processes. Neotectonic processes are closely associated with the formation of the primary tectonic relief, increased or weakened water erosion, etc. “The shape of the slopes is the result of the interaction of slope-forming and slope-modeling processes” (Vartapetov, 2017).

To determine these processes, based on the classification of N. I. Nikolaev (1962), the slopes were divided from very gentle (2-6 °) to overhanging (more than 90 °) (Table 3). Relief indicators that have less than 2 ° are not included in the classification, as they do not belong to elephants (Levers, 2006). From table 2 it follows that about 35% of all slopes of the territory are the slopes of average steepness, about 30% are flat, 25% is steep, and the remaining 10% of the territory is very gentle. These figures are due to the fact that with. Saty is located in the highlands.

Table 2 – A quantitative indicator of the slopes of a certain steepness in Saty

Slope angle, degree	Amount, %	Area, square m
2-6°,	10	335 715
6-15°,	30	343 675
15-30°,	35	345 258
30-45°,	25	339 868

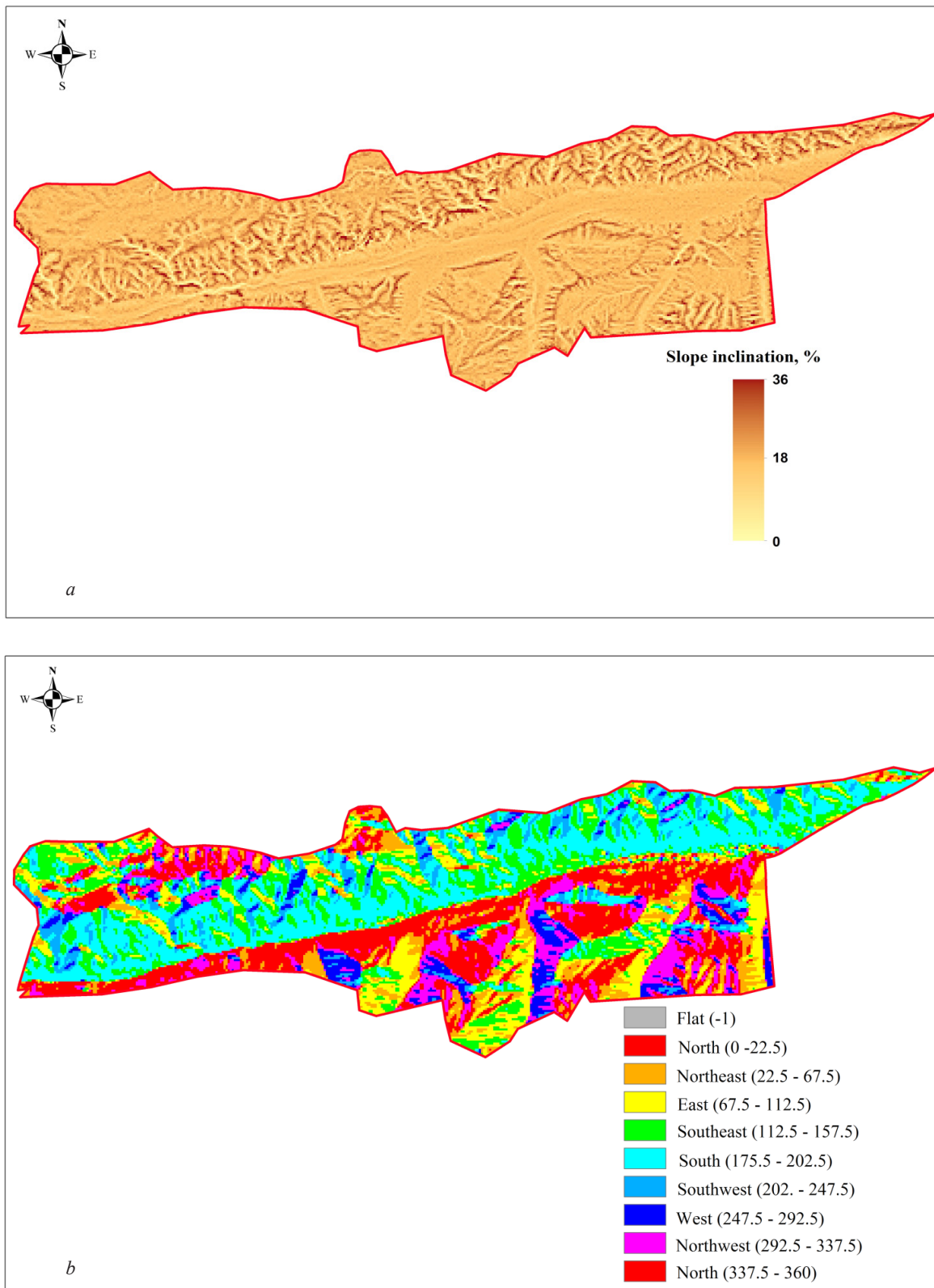


Figure 2 – Derivatives from the DEM model
a – angles of inclination, b – exposure of slopes

Table 3 – Classification by the angle of the slope according to N.I. Nikolaev

Slope angle	Degree
Slightly inclined plains (Very gentle)	2-6°
Gentle	6-15°
Sloppy slopes	15-30°
Sloping slopes	30-45°
Stronger sloping slopes	45-60°
Steep slopes	60-80°
Very steep slopes	80-90°
Overhanging	≥ 90°

On the model of the exposure of the slopes (Fig. 1c), the orientation of the slope surfaces is well highlighted in color. Indicators of terrain slope and exposure are always considered together since these indicators significantly affect vegetation cover, landforms and the intensity of the formation of exogenous processes. Table 4 shows the percentage ratio for 8 points of exposure of the slopes.

Table 4 – The number of slopes of a certain exposure on Saty area

Aspect of elevation	, %
Flat (< 1°)	1
North (22,5-360°)	2
Northeast (22,5-67,5°)	9
East (67,5-112,5°)	10
Southeast (112,5-157,5°)	10
South (157,5-202,5°)	18
Southwest (202,5-247,5°)	13
West (247,5-292,5°)	11
Northwest (292,5-337,5°)	20
North (22,5-360°)	6

From table 4 it follows that the slopes of the northwestern (20%) and southern (18%) exposures prevail. The distribution of these indicators that on the slopes of the north-west exposure is more covered by vegetation than in the south. Since in the southern slopes of significant solar radiation leads to insufficient soil moisture. This factor also affects the density of vegetation.

As a result of the data obtained, a map with complex morphometric areas of the study area was created using the method of relief types. Significant differences in the spatial distribution of the complex morphometric indicator make it possible to identify five morphometric regions within the Saty village, which in general do not coincide spatially with the selected land structures.

Conclusion

Various data sources (GDEM) were analyzed to assess the territories of the Saty village to conduct a geocological assessment of the territories. As a result, calculations were made and quantitative indicators were determined for the slope of the terrain, the exposure of the slopes and geomorphology.

In consequence, by applied methodology determined that a DEM of a scale of 1:50,000 is more suitable since the accuracy of modeling terrain gives an average error of up to 35 m.

The analysis of the territories using GIS technologies made it possible to establish the morphometric indicators of Saty at a quantitative level. In geomorphological terms, the location of Saty is located mainly on the watershed, and the southern part smoothly passes from gentle to steep slopes.

Thus, as a result of the complex analysis of DEM and the obtained data, the average elevation of the relief is about 1900 m, and most of the slopes are characterized as steep (above 2000 m, the slope is up to 36 °).

As a result, these studies can be used to identify hazardous sites and predict subsequent landslide lands, as well as to automatically create a map of the area for zoning.

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