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MORPHOMETRIC ANALYSIS OF THE RELIEF OF THE NORTH-EASTERN SLOPE OF THE GREAT CAUCASUS FOR THE PURPOSE OF TOURISM POTENTIAL (using GIS technologies)

Abstract. Considering that to date, the scientific, theoretical and methodological basis of the use of GIS technologies in tourist geomorphology is not sufficiently developed, the article carried out a morphometric study of the north-eastern slope of the Greater Caucasus in order to develop tourism. The morphometric analysis of the study area we carry out with using a digital relief model (DEM) using the ArcGIS package. The initial data were the results of a Shuttle radar topographic mission (SRTM) radar survey, designed to create a high-precision network of global DEM. Its root-mean-square error is estimated at a height of about 16 m, and the clarity of the position of the nodes of the three-second grid is about 20 m, while in conditions of mountainous relief these indicators become larger. An SRTM image with a resolution of approximately 60 m is useful for implementing morphometric analysis and creating proper maps in a GIS. Image editing related to identification and elimination of minor errors was performed using the ArcGIS package and its Spatial Analyst module.

To establish the general background of the fragmentation of the modern relief, a 5-point scale for assessing morphometric tension was developed and adopted, which includes the degree of horizontal and vertical fragmentation of the territory, the decline of the slopes, etc. The results can be used to create investment projects for the development of tourism on the north-eastern slope of the Greater Caucasus.

Key words: tourism, morphometric analysis, morphometric tension, exogenous processes, ecogeomorphological region, danger, GIS technologies.

Introduction. One of the fastest developing fields in the world in economy is tourism at the moment. In the scope of Azerbaijan tourism is considered as one of the most demanded field as a new form of property for our republic. It is worth to emphasize that having high economic potential, tourism is promoting development of other mixed fields of economy: transport, trade, communication, production of goods of wide consumption, agriculture and etc. Expansion of range of fields in this sector has a number of positive moments, however, the absence of scientific based methodology and corresponding control is definitely reflected in condition of natural environment. Implementation of tourism activities is obliged to be in line with the current legislation in the field of protection of natural environment, and it is important to purse corresponding scientific based evidences taking into account certain territory in order to be in line with this or other types of tourism and recreation [1]. The given system is consisted of several parts where among them the formation of system of environmental geomorphological criteria which is discovering the landscape, tourism zoning of the territory and identification of level of environmental risk [2].

We think that the morphometric analysis of landscape of the territory is the main element of similar studies which can provide an opportunity to evaluate geomorphological touristic resources of North Eastern slope of the Greater Caucasus.

Materials and methodology of study. In Geomorphological achievements they have been analyzed as the main features of the landscape, which can allow us to assess the landscape to which we can include: morphometrics (morphology), dynamic, genesis and age that is also divided to approximately specific

features (the absolute and comparative height, angle of slopes, vertical and horizontal distribution, exposition of slopes and etc.). The above mentioned morphometric condition of accelerated ecogeomorphological state can impact on different level [3,4]. Position and hypsometry of slopes are influencing to ecogeomorphological situation through macro and climate conditions. Horizontal distribution is characterizing the level of differentiation of ecogeomorphological conditions in the spaces, the repeating of slopes of frontal exposition, periods of reformation of landscape complexes. In development ecogeomorphological condition the angles of surface of slopes are defining energy of landscape, activeness and speed of slope processes, also influence to physical, chemical and mechanical features of soil surface, development and productivity of plants, to amount of solar radiation, infiltration of atmosphere precipitations, transformation of energy and elements and other processes which in different levels can impact to organization of landscape complexes and ecosystems [5,6].

Morphometrics is putting certain objectives which are formulating the group of tasks: 1. Description of landscape 2. Explanation of landscape 3. Forecast of formation of landscape [7,8].

One of the important problems for north eastern slope of Great Caucasus which is traditionally used for recreation and tourism is evaluation and appropriate application of tourism resources. Especially important in this issue is the task of evaluation of psychological esthetic features of landscape, which are contributing to strengthening moral and physical state and potential of population [9].

To our opinion, it is desirable to use AKS, air photo plans and photographic maps and sometimes their applications for studying geometry of slopes. The advantage of AKS is that in with them possible to see in details the boundaries of slopes of mountainous territories than in topographic maps. Having forest cover AKS is less informative than topographic maps. That's why it is better to identify the regions where desirable AKS can be applied and where is better to use topographical map [6].

The morphometric analysis of north eastern slope of Greater Caucuses had been conducted by us with the help of digital elevation model (DEM) through using their ArcGIS package. Baseline data were used as a result of radio location shot of shuttle radar topographic mission (SRTM) considered for creation of high resolution network of global DEM. The average square error of it is evaluated on the height approximately equal to 16 meters and resolution of state of three second cell is around 20 meters with the fact that in condition of mountainous landscape the data is becoming higher or larger. SRTM with the resolution approximately 60 meters is useful for realization of morphometric analysis and development of corresponding maps in GIS. Editing image related with identification and eradication of insignificant errors had been conducted with the help of the package ArcGIS and its model Spatial Analyst [10]. The map of angles of slopes of surface of ground (drastic slopes) had been developed by us using the function of Spatial Analyst and its option of surface analysis (figure 1).

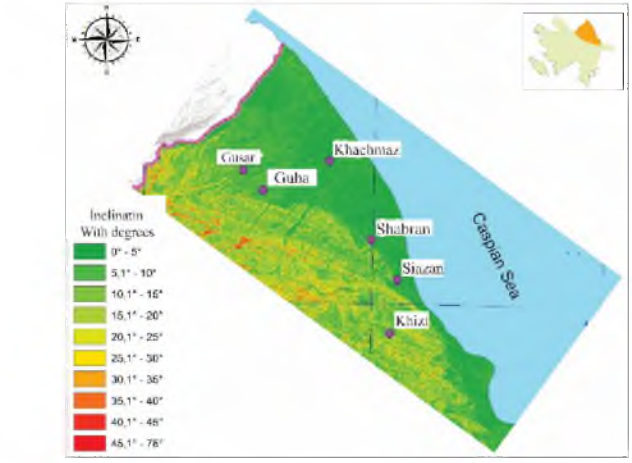

Figure 1 – The map of tilt angles

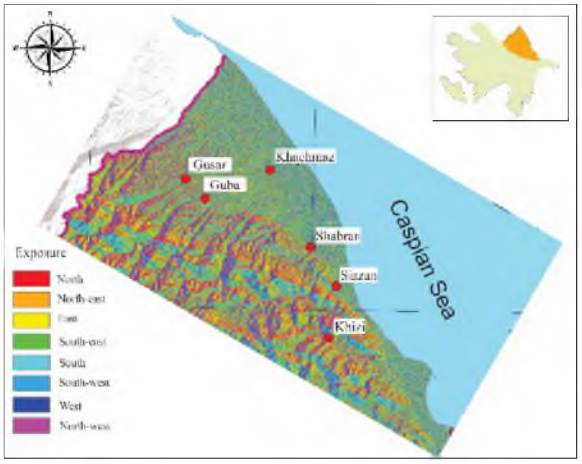

Figure 2 – The map of slope exposure

Initially the map was presented in roster format and later it was converted to vector format. In conclusion there had been developed the polygons of various drastic slopes of vector format maps with angles of slopes. Initially there had been created a hypsometric map with identified elevation levels, then there was calculated maximum and minimum sizes of slopes as well as squares of polygons on elevation

level [7]. At the same place with the same methodology on the bases of digital elevation model there was developed maps of exposition of slopes (figure 2), maps of horizontal and vertical breakdowns (figure 3, figure 4). There had been applied to them geometrical layers such as geological (lithology of rocks), hydrographic network, climate parameters (humidity, atmospheric precipitation, temperature etc.).

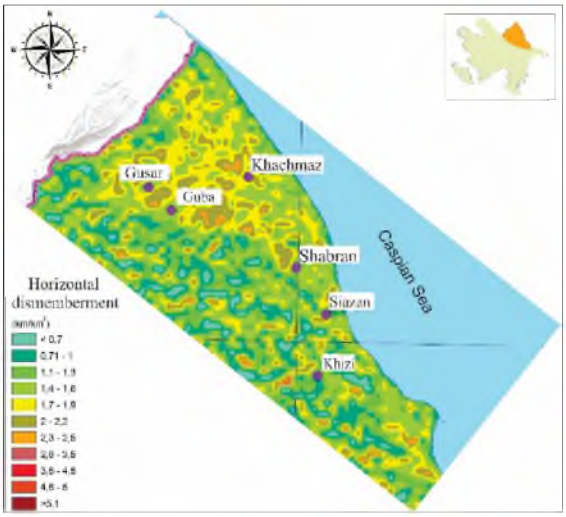

Figure 3 – The Map horizontal partition

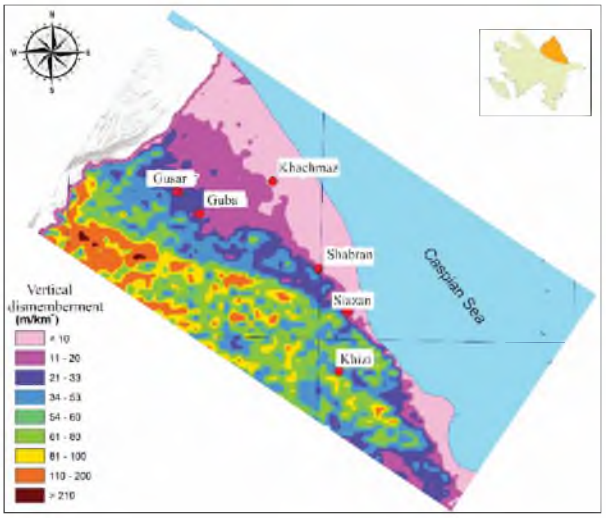

Figure 4 – The map of vertical partition

There had been used by us LANDSAT 8 ASTER GLOBAL DEM (DEM files) on development of maps dated to October 17, 2011 and KS. The works had been conducted in UTM_WGS_1984_UTM_Zone_39N coordination system (Universal Transverse Mercator Coordinate System). There had been conducted analysis using the software ArcGIS 10.5, on the basis of which had been created corresponding maps. One to another had been applied the maps of vertical and horizontal distribution with the help of ArcGIS software (tool boxes) and waited overlay functions, map of angles of slopes, where at the end had been achieve the map of morphometric acceleration (figure 5).

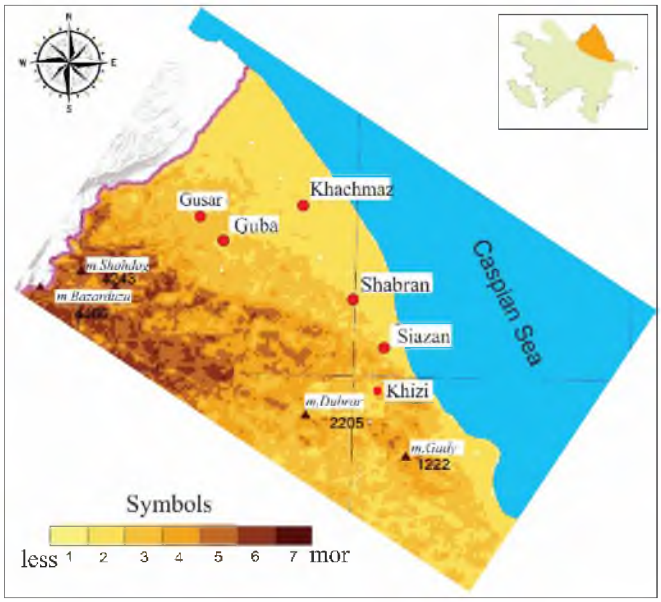

Figure 5 – The map of morphometric tension

With the aim to identify the general background of division of existing landscape there had been developed and accepted 5 scale assessment gradation of morphometric tension (table 1).

Table 1 – Morphometric tension rating scale

Vertical partition (m)	Tilt angles (°)	Horizontal partition (km/m^2)	Scoring in points
>1000	>40	>2,5	V
500-1000	30-40	1,5-2,5	IV
200-500	20-30	1-1,5	III
100-200	10-20	0,5-1	II
0-100	<10	<0,5	I

The calculation of slope is required for evaluation of group of slope processes and it has to be taken in to account in engineering geomorphological studies and etc. Exposition of slope is expressing its relation to processes oriented trough space in equal schedule (insolation, circulation, gravitation): in analysis of interaction directed to lithological, hydrological, geochemical, and aerodynamic flows to landscape differentiation (direct and indirect impact to exogenic processes, sand formulation, plant cover and etc.). The orientation of slopes to influences of erosion denudation activities is characterizing the morphological features of land cover [7].

The results of studies. Mountain geo-system of North eastern slope of Great Caucasus is characterized with intensive breakdown of landscape and they are different on their height, energetic capacity of formation of dangerous fluvioglacial, gravitation, erosion and other landscape forming processes. In given zone it is possible to mention horizontal movement through active disjunctive dislocation of rocks with different genesis and ages. The north eastern slope is characterized with high seismological activeness (7,8 points). Seismological dislocation had enormous impact to development of modern landscape. General tension of horizontal processes in Alpine period of formation of mountains in Great Caucasus in general and in studied region particularly identified in current period with intensive differentiated movements of geodynamic tensions. Multi – character and multi – vectoral alinements conditioned the space distribution and defined the boundaries of morphologically clearly identified steps morpho - structure of given territory. Through these alinement active dynamic zones (Main Caucasus, Siyazan Samur, Valvalichay, Garabulag etc.) is possible to characterize the intensive developing and exogenic landscape formulating processes with high differentiation [11].

The studied territory is divided into following ecogeomorphological regions taken into account the above mentioned data:

Main differentiated massive, Shahdag - Gizil Gaya massive, Tengi - Besh Barmagh massive, Gonagkend - Khaldan series of inter mountain lowlands, Gusar lowland and Samur Davachi lowland. Each of those emphasized ecogeomorphological regions is in line with specific package of tourism resources.

The main Threshold massive is in line with Tufan anticlinoleum where it is consisted of Jurassic clay rocks, sand, limestone which is easily influenced with intensive freeze and physical impact of winds. Landslides and other processes are actively developed in Jurassic slopes of mountains. Also there can be observed soly-fluctuation and defluctuation processes. Main Threshold massive has a perspective on having different category and complexity (Bazarduzu, Tufandag and other mountains).

Shahdag Gizilgaya massive is characterized with the scope of density and depth of disfraction of surface which pre-identified by the intensity modern tectonic movements in line of formation of Samur and Western Caspian transfer zones as well as in a line of their crossing with active Threshold (Siyazan, southern and northern Shahdag, Main Caucasus etc.). Accordingly it is also developed the forms of exervation and modern forms of nivation as well as snow erosion. It has been also distributed the various modern and other types of movements. In drastic slopes it is also distributed mudflows also it is developed deflection and sloifluctuation processes as well as several spaces are occupied with amount flood sources where the areal of them are increased under the influence of technogen factors. Dominating gravitation processes are of different types of land slides and etc. Shahdag-Gizilgaya massive also has a perspective of being included to different category of complexity, and used for skiing sport types (Shahdag mountains, Gizilgaya and others).

The Tengi Besh Barmag massive is consisted of a number of strongly pressured structures among which it is situated similar synclinal zones. The massive is consisted of limestone, clay, sands of various periods and ages. The slopes are drastic and intensively disfracted. The territory has mid mountain and

lowland erosion - denudation landscape. Under the active influence of exomorphodynamic processes the massive is divided through threshold where different forms of landscape are formulated and also there are few waterfalls where is a high land slide risk here which is creating eco geomorphological thred in using the geo-system of given region. Also different types of landslides most developed as well in stone see. Tengi Besh Barmaq massive has a perspective on the point of view of establishment of ecological paths (Velvelechay valley, Laza and Kuzun waterfall and etc.) (figure 6, 7).

Figure 6 – Gorge Velvelichay river

Figure 7 – Laza Waterfall

Gonagkend Khaltan series of inner mountain depression is situated in all high levels and tied different squares of land. High mountainous parts are developed Shahnabat and Khinalig (figure 8) mid mountain and particular low mountain parts Efrin Jimin Gonagkend Altiagaj Khaltan Vostaf Dildilchay Vegver depressions. In depressions of high mountains all the fluvioglacial erosion denudation and gravitation exodynamic processes are taking place. Also it is widely distributed the landslides and other processes [12]. Gonagkend Khaltan series of inner mountain depressions has a perspective on the point of view ecological paths, agricultural and balneological tourism (Altiagaj, Gonagkend and etc.).

Figure 8 – The road to the Khinalig village

In the Gusar lowland from morphotectonical point of view is in line with the developed deflection which had deflection in the recent stages and since late pleosen it was involved to the general process of escalation of Great Caucasus. Here it is highly distributed landslides which can be consisted of different rocks of scopes of values. Their formation is related with the neogen clay rocks in the basin of rivers Velvelchay, Agchay, Garachay, Gudyalchay.

The landslides also developed in the valleys of the rivers Velvelechay and Gilgilchay. The colorful lithological content of rocks, intensive cut of forests are leading to active formation of the network of sloppy mountains and formation of sources of mudflow and floods. In certain places it is possible to meet clay. The Gusar lowland has a perspective in developing agricultural tourism, horse sport and also gastronomy tourism (Gachres, Chilegir etc.).

Samur-Davachi lowland is consisted of alluvial and alluvial delluvial deposits, it is disfracted with ravines, beans, river values and river beds. It is also developed intensive abrasion processes, abrasion and accumulation processes (cost line sands). Samur-Davachi lowland has a perspective in development of seaside beach tourism, fishery and etc. (Nabran, Yalama, Gilazi, Zarat etc.).

Conclusions. From the above mentioned facts it is possible to conclude that morphometric analyses of landscape of north eastern slope of Greater Caucasus through application of GIS is giving an opportunity to conduct quantity assessment of parameters of landscape, e.g. giving appraisal to the level of erosion disfraction, identification of position of slopes, measuring the angles of slopes on earth surface. Besides analysis of multilateral quantity factors of landscape and the developed map of morphometric tension is allowing to reveal the likelihood of opening of conditional type intensity and direction of formation of modern dangerous exogenic processes with the equal scopes and characters of disfraction of landscape, high indicators of which can save the morphometric data. The complex morphometric analysis of the territory through application of GIS are giving opportunity efficiently and in fast way evaluate features of landscape negative features of landscape also for the purposes of forecasting landscape planning. The achieved data can be used and applied not only in several fields of landscape planning (agriculture, land use, construction, environmental activity) as well as in forecasting and functional zoning of territories. The package of morphometric features are allowing to give the assessment to tourism potential of north eastern slope of Greater Caucasus e.g. identifying opportunities of perspective use of various territories for feature development of recreational tourism.

The results of studies are going to provide an opportunity for developing the maps of attractiveness of landscape on conducting zoning for tourism activity. Within the above mentioned research the application of specialized programs which are releasing us from hard, more connected works is giving an opportunity to develop complex morphometric maps of various complexity of space scale and content.

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СОЛТҮСТІК-ШЫҒЫС ДІНІНІҢ МОРФОМЕТРИКАЛЫҚ ТАЛДАУ ТУРИЗМ ПОТЕНТАЛДЫҚ МАҚСАТЫ ҮШІН ҰЛЫ КАУКАЗДЫҢ АЯСЫ (ГАЖ технологиясын қолдану)

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МОРФОМЕТРИЧЕСКИЙ АНАЛИЗ РЕЛЬЕФА СЕВЕРО-ВОСТОЧНОГО СКЛОНА БОЛЬШОГО КАВКАЗА С ЦЕЛЬЮ ТУРИСТИЧЕСКОГО ПОТЕНЦИАЛА (с использованием ГИС-технологий)

Аннотация. Разработка концепции, а вслед за этим и Государственной программы реорганизации и развития туризма в Азербайджане послужили толчком к созданию региональных программ развития туризма. С точки зрения развития туризма северо-восточный склон Большого Кавказа известен своим выгодным географическим положением на берегу Каспийского моря и туристической привлекательностью (горнолыжный спорт, альпинизм, экологические тропы и др.). Учитывая то, что до сегодняшнего дня научно-теоретическая и методологическая основа применения ГИС-технологий в туристической геоморфологии разработана недостаточно, в статье было проведено морфометрическое исследование северо-восточного склона Большого Кавказа в целях развития туризма. Морфометрический анализ исследуемой территории нами проведен с помощью цифровой модели рельефа (ЦМР) с использованием пакета ArcGIS. Исходными данными явились результаты радиолокационной съемки Shuttle radar topographic mission (SRTM), рассчитанной для создания высокоточной сети глобальной ЦМР. Ее среднеквадратическая погрешность оценивается по высоте примерно 16 м, а четкость положения узлов трехсекундной сетки составляет примерно 20 м, при том что в условиях горного рельефа данные показатели становятся больше. Снимок SRTM с разрешением примерно 60 м полезен для реализации морфометрического анализа и создания надлежащих карт в ГИС. Редактирование снимка, связанное с идентификацией и устранением незначительных погрешностей, выполнено с помощью средств пакета ArcGIS и его модуля Spatial Analyst. Карта углов наклона земной поверхности (крутизны склонов) нами составлена с использованием функции Special Analyst и ее

опции Surface analysis. При создании карты вертикального расчленения поверхности изолинии проведены через 100 м. Применяя выбранную градацию 0-20 м, 20-50 м, 50-100 м… 1300-1400 м, 1400 м и более, проведен анализ карты и выявлено, что значения глубины расчленения меняются в широких пределах от 0 до 1900 м. Можно заключить, что максимальные показатели вертикальной расчлененности соответствуют гипсометрически самым высоким территориям. На основе анализа морфометрических карт северо-восточного склона Большого Кавказа выявлено, что глубина расчленения наблюдается в пределах высот от -28 м до 4466 м, т.е. с увеличением абсолютной высоты, увеличивается и глубина расчленения.

Был проведен и сопоставительный анализ карты осредненных уклонов поверхности, где изолинии проведены через 5°. Из карты осредненных уклонов поверхности видно, что количественные показатели осредненных уклонов поверхности меняются в пределах от 0°-1° (в пределах Самур-Девечинской низменности) до 42°-43° (в высокогорной полосе Главного Водораздельного хребта).

На карте горизонтального расчленения поверхности изолинии проведены через 0,5 км/км^2, где количественные показатели меняются от 0,1 до 4,0 км/км^2. Ясно выраженного определенного простирания изолинии не имеют, однако доминирует поперечное направление, т.е. густота расчленения подчинена поперечному морфологическому расчленению территории. Максимальное расчленение 3-4,5 км/км^2 встречается в высокогорной приводораздельной зоне северо-восточного склона Большого Кавказа. Направление изолиний совпадает с направлением главных долин рек. Максимальные значения приурочены к среднегорьям и местами конусам выноса речных долин – 4,5 км/км^2 и более. Минимальные величины горизонтального расчленения свойственны для Самур-Девечинской низменности – 0-0,5 км/км^2.

Для установления общего фона раздробленности современного рельефа разработана и принята 5-ти балльная шкала оценки морфометрической напряженности, куда включены степень горизонтальной и вертикальной расчлененности территории, уклон склонов и др. Полученные результаты можно использовать для создания инвестиционных проектов по развитию туризма на северо-восточном склоне Большого Кавказа.

В процессе освоения территории северо-восточного склона в целях развития туризма немаловажное значение имеет и проблема изучения, оценки и прогнозирования формирования современных опасных природно-разрушительных процессов. Геодинамически активное, дифференцированное развитие набора эндогенно и экзогенно обусловленных процессов рельефообразования неизменно меняет морфологический (морфометрический) вид рельефа, что очень важно учитывать при освоении крайне неустойчивых горных геосистем в целях рекреации. Наряду с этим огромную опасность образуют неожиданно зарожденные и активно проявляющиеся угрожающие или катастрофические эндодинамические и экзодинамические процессы. В статье кратко отражены закономерности проявления современных опасных экзодинамических процессов в разных экогеоморфологических ареалах северо-восточного склона Большого Кавказа. Анализ современных опасных рельефообразующих процессов исследуемой территории, горные системы которого в настоящее время интенсивно осваиваются с целью развития горного, а именно зимнего туризма и др., дает возможность сделать вывод, что в данном регионе Азербайджана самыми опасными процессами являются землетрясения, обвалы, оползни, сели, речная и плоскостная эрозия и др. Все эти процессы формируют общую экодинамическую напряженность. Для целей снижения опасности жизнедеятельности людей, туристическим объектам и др. необходимо выполнять предварительную крупномасштабную экспертную оценку экогеоморфологической обстановки в пределах выделенных экогеоморфологических районах до начала освоения в целях рекреационно-туристического освоения.

Ключевые слова: туризм, морфометрический анализ, морфометрическая напряженность, экзогенные процессы, экогеоморфологический район, опасность, ГИС-технологии

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