ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ
Satbayev University

ХАБАРЛАРЫ

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Satbayev University

NEWS

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN
Satbayev University

SERIES
OF GEOLOGY AND TECHNICAL SCIENCES

6 (450)

NOVEMBER – DECEMBER 2021

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

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Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

«ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Меншіктеуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).
Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігінің Ақпарат комитетінде 29.07.2020 ж. берілген **№ KZ39VPY00025420** мерзімдік басылым тіркеуіне қойылу туралы куәлік.
Тақырыптық бағыты: геология, мұнай және газды өңдеудің химиялық технологиялары, мұнай химиясы, металдарды алу және олардың қосындыларының технологиясы.
Мерзімділігі: жылына 6 рет.
Тиражы: 300 дана.
Редакцияның мекен-жайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., тел.: 272-13-19
http://www.geolog-technical.kz/index.php/en/

Типографияның мекен-жайы: «Аруна» ЖК, Алматы қ., Мұратбаев көш., 75.

«Известия НАН РК. Серия геологии и технических наук».
lSSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы).

Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и общественного развития Республики Казахстан **№ KZ39VPY00025420,** выданное 29.07.2020 г.

Тематическая направленность: геология, химические технологии переработки нефти и газа, нефтехимия, технологии извлечения металлов и их соеденений.

Периодичность: 6 раз в год.

Тираж: 300 экземпляров.

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, оф. 219, тел.: 272-13-19
http://www.geolog-technical.kz/index.php/en/

Адрес типографии: ИП «Аруна», г. Алматы, ул. Муратбаева, 75.

News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Owner: RPA «National Academy of Sciences of the Republic of Kazakhstan» (Almaty).
The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Social Development of the Republic of Kazakhstan **No. KZ39VPY00025420,** issued 29.07.2020.
Thematic scope: geology, chemical technologies for oil and gas processing, petrochemistry, technologies for extracting metals and their connections.
Periodicity: 6 times a year.
Circulation: 300 copies.
Editorial address: 28, Shevchenko str., of. 219, Almaty, 050010, tel. 272-13-19
http://www.geolog-technical.kz/index.php/en/

Address of printing house: ST «Aruna», 75, Muratbayev str, Almaty.

NEWS
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 6, Number 450 (2021), 133-140 https://doi.org/10.32014/2021.2518-170X.129

UDC551.3

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ISSUES OF GEOMORPHOLOGICAL-LANDSCAPE RISK (on the example of the Kishchay river)

Abstract. Today, the problem of developing an assessment of the apparent risk and damage from mudflows and drawing up maps of environmental risk is important. In Azerbaijan, the southern slope of the Greater Caucasus by the number of mudflow basins, the frequency of passage of various mudflows, their power, the volume of removal and the complexity of the conditions for their formation, by the amount of damage caused to economic facilities and residential buildings, is among the most mudflow-hazardous. Based on materials from our own field geomorphological and landscape studies, as well as stock literature, the geomorphological and landscape features and dynamics of the development of mudflow processes are researched, a complete geomorphological characteristic of mudflow centers of the valley of Kishchay river are given, as well as the reasons for their formation are indicated and measures to combat them are proposed. The mudflow hazard analysis mainly used high-resolution space images (SI) (CNES / Airbus, Maxar Technologies (GeoEye-1) and medium resolution (Sentinel-2A and 2B). Based on the interpretation of these images, a landscape map of the Kishchay river basin was compiled.

In the course of the study, it was revealed that mudflow phenomena extremely quickly change individual components of the landscape of the nival, mountain-meadow and mountain-forest zones, which manifests itself in a violation of the integrity of the soil and vegetation cover, in a change in the conditions of moisture, runoff, etc. These processes manifest themselves very quickly and change the landscape within a very short period of time. The sharp complexity of the structure of landscape species testifies to the different intensity of mudflow processes occurring in certain landscape zones.

Key words: mudflow, mudflow center, anthropogenic impact, landscape-geomorphological zones, risk, monitoring

Introduction. In recent decades, the need to solve the problem of protection from dangerous natural processes has been increasingly felt in Azerbaijan. In the conditions of active development of hard-to-reach mountain areas, namely, construction of structures, laying of roads and pipelines, deforestation, overgrazing of livestock, etc., certain natural properties of landscape components change [1, 2]. As a result, the adverse consequences of ill-considered anthropogenic activity cause immediate reactions and interventions [3, 4]. Among natural processes, the leading role is played by manifestations of seismicity and the revitalisation of various ranks of fault disruptions, the activation of avalanches, mudflows, landslides, etc. However, mudflows are the most dangerous. This problem is still very urgent due to global warming, environmentally negative consequences of ill-considered economic human activities, etc. Azerbaijan is one of the regions of the World, often exposed to mudflows. Approximately 572 settlements with a population of about 2 million people and numerous infrastructure facilities are at risk of mudflows.

In terms of the number of mudflow basins, the frequency of passage of various types of mudflows, their power, the volume of removal and the complexity of the conditions for their formation, the amount of damage caused to economic facilities and residential buildings, the territory of the Greater Caucasus is considered to be among the most dangerous regions. Currently, there are 171 settlements with a population of 400 thousand people in Sheki-Zagatala, 154 settlements with a population of 212 thousand people in Guba-Khachmaz, and 70 settlements with a population of 171.2 thousand people in Mountainous Shirvan that are in mudflow hazardous areas. According to Makhmudov R.N. [5], more than 400 mudflows pass through the Greater

Caucasus. 16 rivers are mud-bearing rivers in the Sheki-Zagatala zone, 12 rivers — in the Guba–Khachmaz zone, and 4 rivers – in the Shamakhy – Ismayilli zone.

In the Greater Caucasus, mudflow processes are developed in all landscape and geomorphological zones – from low mountains to high mountain zones. 20% of mudflows occur at an altitude of up to 1000 m, 60% of mudflows occur at an altitude of 1000 – 2000 –2500 m, and the remaining 20% – at an altitude of 2500 to 3500 m. Considering that a large number of people live in river valleys (most of which are mudflows), they are constantly exposed to mudflows.

Mudflows occur as a result of a combination of physical and geographical factors and meteo-climatic phenomena: a large steepness of slopes, intense exogenous processes, heavy rainfall, a small fixation of slopes by vegetation (forest) cover, etc. The development of mudflows within the mountainous territories of the Greater Caucasus is facilitated by the lithological composition of the rocks composing them – the Jurassic clayey shales and clay–sandy–marly facies of the Mesozoic and Paleogene flysch, which determine the formation of mudflows.

In the Greater Caucasus, and, specifically, the southern slope, the most mudflow dangerous area is the Kishchay River basin, where mudflows cause significant economic and social losses (Fig. 1.).

Fig. 1. Destroyed bridge that connected the village of Kish with the district center (Photo —03.07.2016).

Materials and methods. The purpose of this work is to reveal the geomorphological and landscape features and dynamics of the development of mudflow processes based on the materials from our own field geomorphological and landscape studies, as well as stock literature; to give a complete geomorphological description of mudflow origination sites in the Kishchay River valley; to indicate the reasons for their formation; and to propose measures to combat them. During the mudflow hazard analysis, there were mainly used the high-resolution space images (SI) from CNES/Airbus, Maxar Technologies (GeoEye-1), and medium resolution Sentinel-2A and 2B. There were mainly performed a visual and semi-automatic decryption (classification with training) in the ArcGIS.

Research results. SI allows the simultaneous viewing of the structure of individual mudflow basins and to classify channels by exposure based on differences in tone. Good decipherment of mudflow channels at the SI allows identifying the areas of distribution of mudflow origination sites and their migration routes. On SIs of large, medium, and sometimes small scales, they are confidently identified by their position in the relief, formed forms and characteristic textures of viscous-plastic flow. Fresh mudslides, destitute of vegetation, are depicted in a light tone on the SI, and old ones, covered with soil and vegetation, in a darker photo-tone.

Tectonically, the southern slope of the Greater Caucasus Mountain Range is a part of the mega-anticlinorium of the Greater Caucasus, where the Tfan anticlinorium, the Zagatala–Kovdag synclinorium, and the Vandam anticlinorium stand out from north to south.

The river basins are composed of Middle (clayey shale, sandstone) and Upper Jurassic (dense sandstone, limestone, and red merge) and Chalk period. Quaternary deposits consist of alluvial-deluvial, alluvial, torrential, and slope detritus. All subsurface rocks of the Kishchay River basin is intensively breached by numerous cracks and overthrusts – Ilisu, Gumbash, Malkamud overthrusts, and Michikh rupture.

The alpine belt, with a height of more than 3000 m, is destitute of soil and vegetation cover, characterised by sharp rocky peaks and ridges. In some places, the steepness of the slopes is more than 60°. The total area occupied by rocks, placers, and talus is 15.4 km^2 or 5.8% of the entire area of the alpine belt [6, 7, 8]. In addition, glacial landforms (kars, cirques, and trough valleys) and frosty weathering are widely developed here. The upper reaches of the Damarchik, Kaynar, Chukhadurmaz, Donuzja, Sariguneydere, and other rivers are especially intensively subject to denudation. In places, the depth of the valley incisions reaches 700 – 800 m. The valley channels are narrow, slopes are steep-sided, and a huge amount of loose material accumulates at the soles. Large density and depth of dissection, narrow valleys with a stepped profile, and steepness of slopes created favourable conditions for the formation of mudflows. The coefficient of dissection density in the Kishchay River basin is 0.62 km^2, which is the highest of all the mudflow rivers on the southern slope of the Greater Caucasus. The average width of the basin is 8 km. The river basin is intensively dissected and consists of rocky areas.

It is considered that the distribution of mudflow origination sites of various genetic types is one of the important parameters of the mudflow hazard of the basin. Centres feeding mudflows with fragmental materials, B.A. Budagov [6], subdivide the following morphological groups: moraines, placers, avalanches, taluses, landslides, fans of lateral rivers, terrace, floodplain, and channel deposits.

For instance, powerful talus covers are located in the region of Seyidyurd, Nokhurlar, Chukhadurmaz, Chakhil, Chaylakhan, Goytepe, at the head of the rivers Garanemler, Dereyurd, Boyukshor, Agilitala, Damarchik, Gaynarja, Sariguneydere, Donuzja, Gizilbere, Gengajala, etc. (all are tributaries of the Kishchay River).

Avalanches play a huge role in mudflow formation, occurring mainly within the high mountain zone, namely in the basins of the upper reaches of the tributaries of the Kishchay River – Damarchik, Sariguney, Donuzja, Chukhadurmaz, etc. Moraine deposits feeding the Kishchay River are located in the upper tributaries (at an absolute altitude of 2500 – 700 m), namely, on the right bank of the Damarchik River, on the upper course of the Kaynarja River (the source of the left tributary of the Garanemler River, etc). Landslides, which are widespread in the basins of the rivers of the southern slope of the Greater Caucasus Mountain Range, are also involved in the feeding of mudflows. These include landslides in the river valleys of Gizibere, Goytepe, Chukhadurmaz, Gaynarja, etc. An important role in mudflows is played by terrace deposits, the material of which is eroded during the passage of mudflows, which is an additional feeding of the flow.

The main reason for the manifestation of mudflow processes in the Kishchay River basin is the development of large rocky and talus areas, the funnel-shaped nature of mudflow origination sites, composed of semi-stable rocks, the rectilinear structure of narrow valleys, complicated by waterfalls, gorges, and steep slopes. These conditions, in combination with climatic factors – heavy rainfall after long drought season — favour the formation of structural (mud-stone) mudflows (Fig. 2, 3).

One of the main factors in the passage of mudflows is also the morphological features of the Kishchay River valley. The outcrops of bedrock, inhibiting and changing the direction of mudflows, are rare. The movement of mudflows on a flat slope favours gaining high speed.

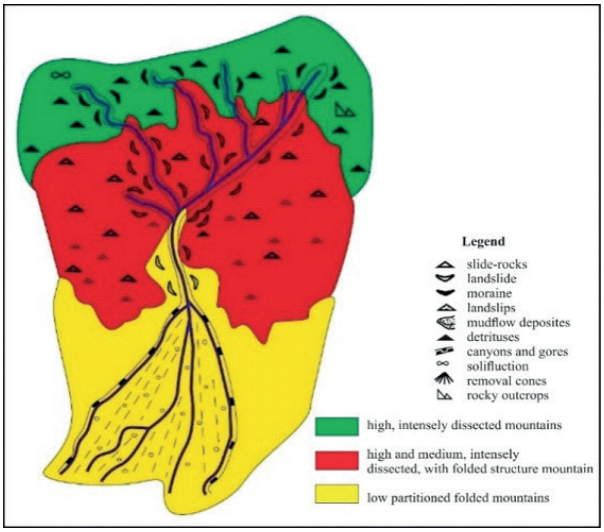

Fig. 2. Geomorphological map of the Kishchay river
Based on materials from Budagov B.A. [6], Alizade E.K., Tarikhazer S.A. [1, 8] and others.

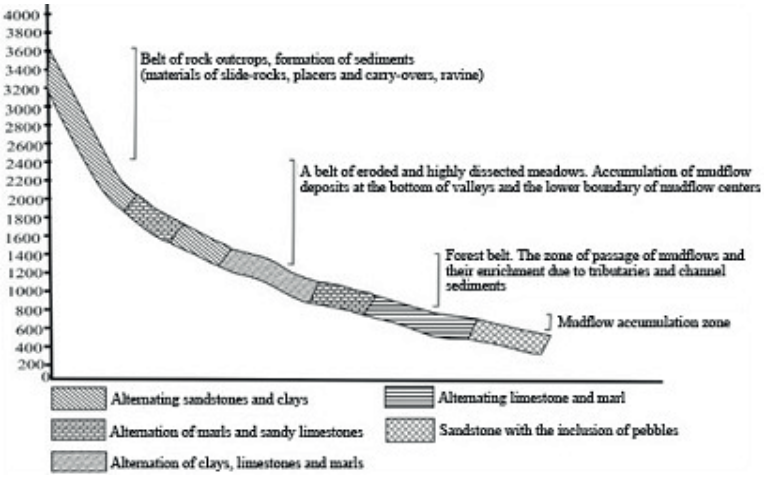

Fig. 3. Longitudinal geological and geomorphological profile of the Kishchay river

On the basis of field research and landscape mapping at "key areas", the influence of mudflow processes on the differentiation of landscapes on the southern slope of the Greater Caucasus has been studied. It has been established that mudflow phenomena extremely quickly change individual components of the landscape of the nival, mountain-meadow, and mountain-forest zones, which is manifested in the violation of the integrity of the soil and vegetation cover, in the change in the moisture conditions, water flow, etc. These processes manifest themselves very quickly and change the landscape in during an extremely short period of time [9]. The sharp complexity of the structure of landscape types indicates a different intensity of mudflow processes occurring in certain landscape zones. Apparently, the most intensive natural processes occur in the mountain-forest zone (Table 1).

Mudflow dangerous Kishchay River flows through the mountain-forest landscape belt at a great distance (11.3 km), where accumulative terraces, cones of lateral tributaries and ravines, floodplain and riverbed deposits are widespread.

Development of mudflow processes along high-altitude landscape zones

Table 1.

Name of mudflow river basin	**Area of mudflow river basin (km²)**	**Nival-subnival landscape zone**		**Mountain meadow landscape zone**		**Mountain-forest landscape zone**	
		Total area of zone in the basin	The area of mudflow centers (%)	Total area of zone in the basin	Mudflow centers area (%)	Total area of zone in the basin	Mudflow centers area (%)
Kishchay river	154,4	16,00	66,8	36,1	59,2	88,9	18,3

Accumulative terraces in the Kishchay River valley are represented by low levels due to poor preservation. Due to the anthropogenic impact, these terraces have peculiar landscape complexes. The terraces, located far from settlements, are covered with forest timber species, represented by Hornbeam, Beech, Maple, and various wild fruit trees developed on alluvial forest soils. Despite the development of trees, these terraces are intensively washed away during floods and mudflows and reduce their areas [10, 11]. Relatively high and ancient terraces, where Kish and Okhud villages are located, differ from the landscapes of the adjacent territories despite the development in the mountain-forest belt due to anthropogenic factors in landscape complexes. These accumulative terraces are intensively washed away.

Fan deltas of lateral tributaries and ravines are often encountered in the valley of the mudflow dangerous Kishchay River. Alluvial cones of intensively growing lateral ravines occupy a huge area, and intensive weathering processes occur on their slopes, the materials of which, during intense rainfall precipitation, move down the slope and periodically accumulate on different parts of the cone. Therefore, landscape complexes of different ages of low taxonomic rank (facies) with different physical and geographical conditions are developed here (Fig. 4).

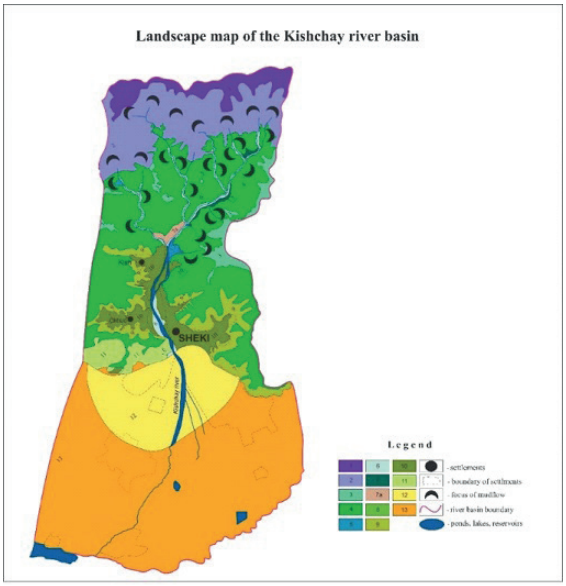

Fig. 4. Landscape map of the Kishchay river basin

Legend of the landscape map of the Kishchay river basin

Subnival-nival landscapes with strongly partitioned relief of high peaks and ridges of mountain ranges, composed by Jurassic clay sandstones with rocky and scree vegetation, on immature mountain-meadow eroded soils;

High-altitude alpine meadows with strongly and mid-partitioned relief, composed of clay-shale and sandstone-limestone sediments cut by extensive mudflow focuses with low-growing grassy cover on mountain-meadow turf soils without a real summer period;

Mid-partitioned steep (30–35) slopes and peaks, composed by sandstones with well developed subalpine meadows on mountain meadow peaty soils;

Medium and strongly partitioned steep slopes composed by sandstones and limestones with oak-hornbeam and beech forests on brown forest soils;

The floodplain terraces and the upper parts of the debris cone composed by mudflow deposits with motley grasses and shrubs on alluvial soils;

The floodplains of mudflow rivers with different balled bouldery-pebbles material with loams;

Flood-plain river terraces covered with bouldery-pebble material, as well as mudflow deposits with shrubs on alluvial meadow soils;

7a. Anthropogenic forests «Sham Bagi» in the area of the Kish River Basin;

Weakly and mid-partitioned slopes, jagged by linear mudflow gulles, composed by sandstones and limestones with coppice oak-hornbeam, partially beech forests on mountain-forest carbonate soils;

Weakly partitioned glacises, jagged by linear mudflow gulles, composed by sandstones and limestones on brown soils with lighted forest cover (oak-hornbeam forests) with anthropogenic influence;

Accumulative terraces with incuted lateral tributaries on alluvial-meadow-forest soils (requiring fastening from destruction by coast-protecting walls) intensively anthropogenically modified

Low mountain-foothill mid-partitioned slopes, jagged by temporary streams with sparse forest shrub vegetation;

Upper sections of modern debris cones composed by large mudflow sediments with dry valleys, temporary riverbeds with motley grass, shrubs, and cultural landscapes on alluvial soils;

Peripheral zone of debris cones formed by uneven-age mudflow sediments, jagged by numerous horns of the main rivers and intensively anthropogenically modified (settlements, agricultural areas).

Hornbeam-beech forests (with Maple and Silver Poplar) are developed on alluvial forest soils on relatively ancient and high parts of the cone. Above-floodplain-terrace and channel sediments are also widely developed in the valley of the Kishchay River. The width of these channels in the area of Kish village is 200 – 250 m, and in the area of Okhud, it reaches 700–750 m and more. Shapeless boulders of various sizes with aggregates are developed on floodplain terraces, destitute of soil and vegetation cover. The morphological structure of the surface of this part of the mudflow valley is changed by mudflows, and there is often an alternation of mudflow boulders [12, 13].

Discussion. The research discovered an intensifying occurrence of destructive natural phenomena in the studied mountainous regions of Azerbaijan and all orogenic zones, which is caused by an increasing effect of endo- and exogenous factors. The analysis of the factors that affect the development of dangerous natural phenomena found that besides commonly known causes that were described by other researchers [5], an important role is played by the geomorphological factor, in particular, their confinement to the weakest plexuses of mountains – intersections of faults and fractures of various directions and orders.

Therefore, these processes should be considered in combination when forecasting the risk of occurrence of dangerous natural phenomena. This approach, which takes into consideration the entire set of factors, was taken to draw the schematic maps of mudflow hazard areas.

It is also worth noting that besides the geomorphological factors, which are the main cause of dangerous natural phenomena, climatic factors also play a significant role. In most cases, they serve as the catalyst of these phenomena and a factor that can upset the natural balance.

The research also focused on the manmade influence on montane ecosystems The effect of human activities on the occurrence and development of dangerous geomorphological phenomena was proven once again. It was found that deforestation, overgrazing, and steep slopes in the mountainous regions of Azerbaijan created prerequisites for the occurrence of mudflows with scree, landslide, and rock-fall materials.

Conclusion. The abovementioned allows asserting that as a result of the intensification of anthropogenic impact and the values of hydrometeorological factors, the hazards and risks of mudflow processes on the Kishchay River have significantly increased. In recent years, the areas of alpine and subalpine meadows of the tributaries Sariguneydere and Chukhadurmaz have almost completely disappeared due to excessive overgrazing of livestock. The riverbed of Damarchik River intensively exposed to numerous material of landslides, placers, and talus.

Conducted landscape analysis of the Kishchay River basin made it possible to reveal that the territorial differentiation of the landscapes of mudflow origination sites is mainly due to the high density and deep dissection of the relief, the steepness of the surface, and the exposure of slopes. Consequently, intra-landscape differentiation and landscape diversity of morphological units emerge. The development and distribution of landscapes of mudflow origination sites strictly obey the laws of altitudinal zonality of all landscape-forming factors, and, depending on the spatial orientation of the slopes, the nature of these phenomena and the distinctness of their differentiation are manifested in different ways.

To reduce the negative impact of mudflows on various objects, regular monitoring should be carried out in order to prevent their possible activation. It is considered that this study will make a certain contribution to solving such an urgent problem as forecasting mudflows in order to ensure sustainable development of mountainous areas.

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ГЕОМОРФОЛОГИЯ-ЛАНДШАФТЫҚ ҚАУІПТІҢ МӘСЕЛЕЛЕРІ (Кишчай өзенінің мысалында)

Аннотация. Бүгінгі таңда сел тасқынынан көрінетін қауіп пен залалды бағалауды әзірлеу және экологиялық қауіп карталарын жасау мәселесі өзекті болып отыр. Әзірбайжанда Үлкен Кавказдың оңтүстік баурайында сел бассейндерінің саны, әртүрлі селдердің өту жиілігі, олардың күші, жою көлемі және олардың пайда болу жағдайларының күрделілігі, шаруашылыққа келтірілген зиянның мөлшері бойынша нысандары мен тұрғын үйлері сел қауіптілерінің қатарында. Өзіміздің далалық геоморфологиялық және ландшафтық зерттеулердің материалдары, сондай-ақ қор әдебиеттері негізінде сел процестерінің даму динамикасы мен геоморфологиялық және ландшафттық ерекшеліктері зерттелді, Кишчай өзені аңғарының сел орталықтарының толық геоморфологиялық сипаттамасы берілді, сондай-ақ олардың пайда болу себептері көрсетіліп, олармен күресу шаралары ұсынылады. Сел қаупін талдау кезінде негізінен жоғары ажыратымдылығы бар ғарыштық суреттер (SI) (CNES

/ Airbus, Maxar Technologies (GeoEye-1)) және орташа ажыратымдылықтағы (Sentinel-2A және 2B) пайдаланылды.Осы суреттерді түсіндіру негізінде ландшафт картасы жасалды. Кишчай өзенінің бассейні құрастырылды.

Зерттеу барысында сел құбылыстары топырақ пен өсімдік жамылғысының тұтастығының бұзылуынан көрінетін нивальды, таулы-шалғынды және таулы-орманды аймақтардың ландшафтының жеке компоненттерін өте тез өзгертетіні анықталды. ылғалдылықтың, ағынның және т.б.ландшафт түрлерінің құрылымының күрделілігі, ландшафты аймақтарда болатын сел процестерінің әр түрлі қарқындылығын көрсетеді.

Түйінді сөздер: сел, сел орталығы, антропогендік әсер, ландшафттық-геоморфологиялық аймақтар, тәуекел, мониторинг.

УДК551.3

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ВОПРОСЫ ГЕОМОРФОЛОГО-ЛАНДШАФТНОГО РИСКА (на примере р. Кишчай)

Аннотация. Одной из актуальных проблем является проблема разработки методики оценки видимого риска и ущерба от селей и составления карт экологического риска. В Азербайджане южный склон Большого Кавказа относится к числу наиболее селеопасных по количеству селевых бассейнов, частоте прохождения различных селей, их мощности, объему отвода и сложности условий их образования, по размеру ущерба, нанесенного хозяйственному хозяйству, объектам и жилым домам. На основе материалов собственных полевых геоморфологических и ландшафтных исследований, а также фондовой литературы исследованы геоморфологические и ландшафтные особенности и динамика развития селей, дана полная геоморфологическая характеристика селей долины реки Кишчай. а также указаны причины их образования и предложены меры по борьбе с ними. В анализе селей в основном использовались космические снимки высокого разрешения (SI) (CNES / Airbus, Maxar Technologies (GeoEye-1) и среднего разрешения (Sentinel-2A и 2B). На основе интерпретации этих изображений была составлена ландшафтная карта бассейна реки Кишчай.

В ходе исследования было выявлено, что селевые явления крайне быстро изменяют отдельные компоненты ландшафта нивальной, горно-луговой и горно-лесной зон, что проявляется в нарушении целостности почвенно-растительного покрова, в изменении условий увлажнения, стока и др. Эти процессы проявляются очень быстро и меняют ландшафт в течение крайне небольшого промежутка времени. Резкая сложность структуры видов ландшафтов свидетельствует о разной интенсивности селевых процессов, происходящих в тех или иных ландшафтных зонах.

Ключевые слова: сель, селевой очаг, антропогенное воздействие, ландшафтно-геоморфологические зоны, риск, мониторинг.

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ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Редакторы: *М.С. Ахметова, А. Ботанқызы, Д.С. Аленов, Р.Ж. Мрзабаева*
Верстка на компьютере *Г.Д.Жадыранова*

Подписано в печать 15.12.2021.
Формат 60x881/8. Бумага офсетная. Печать – ризограф.
4,6 п.л. Тираж 300. Заказ 6.

Национальная академия наук РК
050010, Алматы, ул. Шевченко, 28, т. 272-13-19