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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

THE EFFECT OF ELEVATION DIFFERENTIATION OF THE NORTH-EASTERN SLOPE LANDSCAPES OF THE GREATER CAUCASUS ON THE FORMATION OF RIVER FLOW

Speciality:	5408.01 – Physical geography and biogeography, soil geography, geophysics and geochemistry of landscapes
Field of science:	Geography
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GENERAL CHARACTERISTICS OF WORK

Rationale and level of development of the research topic. The role of all factors engaged in the formation of the flow should be clarified in this process since rivers are an essential component of the natural landscape. Over the years-long period, the influence of both natural and anthropogenic factors changes the water regime and flow indicators of rivers. The effect the economic and agricultural activities, carried out in the river basins and channels, has on the river flow increases each year.

Object and subject of the research. The landscape structure of the area should also be analysed to study the river flow. The landscape is formed due to the interaction of physical and geographical elements, i.e climate, relief, geological structure, soil-vegetation cover, and other factors. The set of these factors causes the flow indicators of the rivers to differ. The importance of the landscape-hydrological approach in conducting hydrological studies is excellent from the point of view of investigating the flow distribution.

In this connection, the landscape structure of areas should be considered while studying the water regime of rivers of different areas. Studying the relationship between landscapes and the hydrographic network is of great importance in the forecasting of river flow, in the study of the distribution of flow in altitude zones, in the calculation of the maximum water consumption of rivers, in the selection of similar basins for the extension of hydrological series, etc.

The study of rivers based on landscape features requires landscape-hydrological zoning. Landscape-hydrological zoning is also important for identifying zonal-azonal regime rivers, studying river regime characteristics, and determining flow indicators.

Purpose and objectives of the research.

The primary purpose of the research is to determine the impact of landscape differentiation on the rivers of the northeastern slope of the Greater Caucasus. To achieve the set goal in the dissertation work, the following objectives are planned to be implemented:

1. Landscape analysis of the study area;
2. Analysis of hydrographic network structure;
3. Assessment of the location of hydrological observation points by

landscape types;

4. Assessment of physical-geographical and anthropogenic factors affecting river flow;
5. Determination of flow indicators of rivers based on the landscape zones;
6. Landscape-hydrological zoning of the northeastern slope of the Greater Caucasus.

Research methods. The research work has been developed using the materials of hydrological data, landscape, climate, soil, and elevation maps of 1928-2022. Maps have been compiled using ArcGIS software during the research process. Morphometric indicators and flow data of river basins and rivers are taken from Hydrological yearbooks and the National Hydrometeorological Department.

Zonal-hydrological, geographic-hydrological, geographic interpolation, Horton method, comparison, and statistical and mathematical methods have been used in the dissertation.

In the dissertation, for the first time, the finding of water consumption depending on the landscapes on the northeastern slope of the Greater Caucasus and the landscape-hydrological zoning in the area were carried out.

The main provisions of the dissertation submitted for defence:

1. Evaluating observation points in terms of landscape zones;
2. Regularities of change of different indicators of river flow by height;
3. Determining the impact of landscape differentiation on river flow;
4. Landscape-hydrological zoning of the northeastern slope of the Greater Caucasus.

The scientific novelty of the research. The research has identified the following scientific innovations:

1. The influence of landscape types on the annual flow of rivers has been evaluated;
2. The rivers of the northeastern slope of the Greater Caucasus have been grouped according to the typological approach;
3. The regularities of changes in various characteristics of the river flow over the years-long period have been determined;

4. River flow rates have been determined by the Horton method;
5. The landscape-hydrological zoning of the northeastern slope of the Greater Caucasus has been conducted using a zonal approach;

The theoretical and practical significance of the research. The results and materials of the conducted research can be used at the Research and Project Institutes of the Ministry of Ecology and Natural Resources, Department of Hydrometeorology, and water consumers. The results obtained can be utilised for educational purposes by improving hydrological monitoring stations and opening new stations on the rivers on the northeastern slope of the Greater Caucasus.

Approbation and application of the dissertation. The main content of the dissertation and the obtained results were presented at the following conferences:

At the All-Russian Young Scientists Conference (Voronezh, 2015)", 1st International scientific conference of young scientists" of the Ministry of Education of the Republic of Azerbaijan and Ganja State University (Ganja, 2016), at the International scientific-practical conference on "Water resources, hydrotechnical facilities, and environment" dedicated to the 100th anniversary of the "Shollar-Baku Waterworks Complex (Baku, 2017), Sumgayit State University "Modern Problems of Geography" Republican scientific conference (Sumgayit, 2019), Modern Problems of Geography: Integration of Science and Education II International scientific-practical conference dedicated to the 100th anniversary of National Leader Heydar Aliyev (Baku, 2023). Main results of the dissertation are reflected in 14 articles and theses.

The name of the institution where the dissertation work was carried out. The dissertation work was carried out at the Department of General Geography of the Azerbaijan State Pedagogical University.

The structure, content, and scope of the dissertation.

The dissertation work has been conducted in accordance with the requirements set by the Supreme Attestation Commission under the President of the Republic of Azerbaijan.

The dissertation work consists of introduction (5223 symbols), 4 chapters – chapter I (62469 symbols), chapter II (61761 symbols), chapter III (44676 symbols), chapter IV (20300 symbols), conclusion and suggestions (2238 symbols), and a literature review. In general, the scope

of the work is (196767 symbols) 170 pages.

THE MAIN CONTENT OF THE RESEARCH

The introduction of the dissertation defines the relevance of the topic, level of study, purpose and objectives, theoretical and methodological bases, information base, scientific novelty, and practical importance.

The first chapter of the dissertation covers "The main features of the territorial differentiation of the landscapes of the northeastern slope of the Greater Caucasus" and consists of two paragraphs. This chapter studies the physical and geographical conditions and landscapes of the research area in detail.

The northeastern part of the Greater Caucasus, which was chosen as the research object, has a particular complex orographic shape, and is composed of several mountain ranges, mountain branches separated from them, and inter-mountain depressions. There is a glaciation center at an altitude of 3500-3600 m in this part of the Greater Caucasus region. The Greater Caucasus generally consists of 8 orographic units with specific characteristics: Southern Slope, Ganikh-Eyrichay Valley, Shaki-Gabala frontal mountain zone, North-eastern Slope, Samur-Devachi Plain, South-eastern part, Shamakhi-Gobustan, and Absheron.

The Greater Caucasus mountains intersect at our territory from the Tinov-Rosso peak, located on the border with Georgia. The northeastern part of these mountains consists of the Main Caucasus and the Yan Range. The watershed, and high peaks of these ridges have an alpine type relief, and are characterised by the extensive development of steep rocky slopes and swelling peaks formed under the influence of snow and ice cover and glaciers.

B.A.Budagov[1], M.A.Museyibov[2] have shown in their researches that the Bashsuayriji Ridge is crooked in the area from Tinov-Rosso Peak to Bazarduzu Peak. The inclination is observed in the ridge in the northern and southern directions.

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[1]Budagov, B.A. Modern and ancient glaciation of the Great Caucasus part of Azerbaijan / B.A. Budagov. - Baku, - 1965. - 158 p.

[2]Museyibov, M.A. Physical geography of Azerbaijan / M.A.Museyibov. - Baku: Maarif, - 1998. - 399 p.

B.A.Budagov divides the northeastern slope of the Greater Caucasus into four main altitude zones[3]:

1. Plain belt - covers the areas between 26-28 meters and 200 m altitude. In the area where the rivers come out into the plains, they create their convex surface and fan-like expansion cones towards the erosion base. Depending on the water consumption of the rivers, the size of the basin and the amount of materials washed away, the size of the conveying cones is also different.

2. Low mountainous belt covers heights of 200 meters and 800-1000 meters. Compared to the high and medium highlands, the terrain is less fragmented.

3. The middle mountainous belt covers areas between 800-1000 m and 2000-2200 m. In this belt, the relief has been deeply cut as the water consumption in the rivers has changed sharply. While the depth of the river valleys reaches 800-1000 m, the depth can reach 1500-2000 m in the areas of Gusarchay and Gudyalchay rivers, cut by the Shahdag and Kizilgaya plains. Landslides are widespread within the belt. Most of the landslides can be found in the areas between the Atachay and Valvalachay rivers.

4. The High Mountain belt covers areas of 2000-2200 m and above. It corresponds to the heights of the Greater Caucasus and the Yan Range. Trough-shaped valleys formed by ancient glaciers have developed in the high mountain zone. It consists of mountain meadows up to 3200 m altitude. Landslides and avalanches are common in the mountain-meadow zone. Within the belt, there are valleys of the tributaries that form the main rivers.

River terraces and moraine sediments could be encountered in some areas of the northeastern part of the Greater Caucasus. Terraces of erosional origin could be encountered in the southern and southwestern parts of the territory. Terraces of erosion-accumulation origin have been formed in the valleys of Valvelachay, Karachay, Chagacigchay, Agchay, Gudyalchay, and other rivers. The central and northeastern part of the plain is rich in terraces of accumulative origin. The variety of physical-

[3] Budagov, B.A. Modern natural landscapes of the Azerbaijan SSR / B.A.Budagov. - Baku, - 1988, - 134 p.

geographical conditions in the study area also shows its influence on the number of elevation zones of the landscape and the variety of landscape types. The landscapes areas and landscape types in the study were calculated using the ArcGIS program on the 1:600000 scale landscape map of Azerbaijan by B.A.Budagov (Table 1).

Table 1

Landscapes of the northeastern slope of the Greater Caucasus

№	Landscapes	Area, km^2	%
1	The nival, partially nival-glacial landscape of the highlands (3000-4500 m)	279.3	4.01%
2	Alpine and subalpine meadows of high mountains (2000-3000 m)	1009.1	14.49%
3	Broad-leaved forests and post-forest meadow-shrubs of medium highlands and partly low highlands (600-2200 m)	1644.3	23.61%
4	Broad-leaved forests of the low highlands (100-1400 m)	1363.8	19.59%
5	Lowland (200-1200 m) arid forest-shrub landscape	1473.8	21.17%
6	Semi-desert landscape of low and front highlands (300-1200 m)	100.2	1.44%
7	Meadow-forest landscape of plains and lowlands (-27-600 m)	445.7	6.40%
8	Dry-desert landscape of the front highlands (-27-100 m)	563.2	8.09%
9	Swamp-meadow landscape of the lowlands (-27-50 m)	83.9	1.20%
Total		6963.3	100%

The largest part of the territory - 24% - is covered by the broad-leaved forests and post-forest meadow-shrub landscapes of the Middle Highlands and partially the low highlands, and the least part - 1.2% - by the swamp-grass landscape of the Lowlands.

The second chapter of the thesis is called "**Influence of landscape differentiation and other factors on the formation of the flow**". This

chapter studies the factors affecting the flow regime of the rivers. In this regard, the height model of the relief has been drawn up, and the length and basin areas of the rivers have been calculated for the landscapes to determine the effect of the vertical differentiation of the landscape on the flow of rivers and to evaluate the influence of physical-geographical factors in the region under study. The elevations covered by the landscape types, where the rivers are located, have been determined and the position of the hydrological points on the landscape have been investigated (Table 2).

It was revealed that most vstations are located within the range of 500-1500 meters. It should be mentioned that observations are generally not made within the nival, partially nival-glacial, and subnival landscape of intensively fragmented high mountains. In this regard, a connection was established between the years-long average water consumption of river stations and the absolute height of the stations since it is vital to determine the amount of flow at any height. Following the results of the study, the rivers of the area were divided into four groups based on their hydrographic indicators:

Group 1 includes the upper and middle streams of the Gudyalchay and Gusarchay rivers;

Group 2 – the upper and middle streams of Valvalachay, Agchay, Khinaligchay, and Garachay rivers;

Group 3 – Gudyalchay's downstream, Gilgilchay, Chagachigchay, Aghchay, Kharmidorchay-Khaltan, Guruchay, and Derkchay rivers;

Group 4 – Shabranchay, Atachay, and Davachichay rivers.

Table 2

The position of the observation points on the north-eastern slope of the Greater Caucasus in terms of landscape types and heights

Landscape types	Dry-steppe landscape and semi-desert landscape of plains and lowlands	Moderately fragmented lowland broad-leaved forest landscape	Broad-leaved forest and post-forest forest-shrub landscape of sharply fragmented mid-mountain and semi-desert landscape of foothills	Alpine, subalpine meadows and meadow-steppe landscape of intensively fragmented highlands
Height	0-500 m	500-1000 m	1000-1500 m	1500-2500 m
Observation points	Gudyalchay-Nizova	Gudyalchay-Kupchal	Gusarchay-Kuzun	Gudyalchay-Khinalig
	Davachichay-Khalfalar	Aghchay-Sukhtagishlag	Gusarchay - Anikh	Khinaligchay-Khinalig
	Gilgilchay-Chalgan	Karachay-Ruk	Gusarchay-Gusar	Agchay-Jeck
		Chagachigchay-Rustov	Guruchay-Susay	
		Valvalachay-Tangaalti	Gudyalchay-Giriz	
		Kharmidorchay-Khaltan	Valvalachay-Nohurduzu	
		Shabranchay-Zeyva	Derkchay-Derk	
		Atachay-Altiaghaj		

The research applied the typological approach to the grouping of rivers and obtained the following mathematical expressions for the relations obtained:

For rivers of Group 1,

$$Q = -0.003H + 9.1233$$

$$R = 0.7671$$

For rivers of Group 2,

$$Q = -0.0017H + 4.5062$$
$$R = 0.8207$$

For rivers of Group 3,

$$Q = -0.0018H + 2.4068$$
$$R = 0.8653$$

For rivers of Group 4,

$$Q = -0.0005H + 0.6122$$
$$R = 0.8501$$

Obtained mathematical expressions will make it possible to determine the amount of water consumption at any height in river basins. Also, considering the natural conditions of the area, it is possible to determine the flow effect of landscape differentiation in the vertical direction and the water consumption and flow module within the landscape zone of each river.

The reason for grouping the regional rivers in this form is the variety of relationships between water consumption and height in river basins. According to study results, there is an inverse relationship between altitude and water consumption.

The territory, arrangement, natural and at the same time anthropogenic factors of the rivers affect their grouping. Thus, the Guruchay basin, located between the Gusarchay and Gudyalchay basins, does not belong to Group 1 but to Group 3. The reason for this is not only water consumption but also relief and anthropogenic factors. That is, unlike the other two rivers, the water of the Guruchay River is completely used for irrigation. River stations included in the first group are rivers with spring-summer rush. Snow and glacier waters play a major role in feeding these rivers. However, like other rivers of the group, the Guruchay River has a flood regime, and its feeding is dominated by rainwater. Among the rivers included in Group 3, Guruchay and Agchay Rivers are formed by the combination of springs.

Although Agchay-Jek and Khinalygchay-Khinalig are located at the beginning of Gudyalchay and snow and glacier water prevail (up to 70%) in feeding these rivers like the ones listed in Group 1, they are not included in Group 1 but in Group 2. Thus, each of these rivers unites to form the Gudyalchay River. These rivers flow only in the

nival and alpine belts. Although karst rocks are not widespread in the country, they are present in the river basins of the research area.

It is assumed that underground water exchange takes place in the upper parts of the Gudyalchay River. The effect of karst flow is greater in the low water period[4]. A large part of precipitation does not take part in evaporation by filtering through the soil-rock layer. The infiltration process is intensive in the river basins composed of permeable soft rocks. These rocks play the role of moisture accumulator, and as a result, the river flow is regulated. [5] The average years-long value of minimum winter flow in the Gudyalchay and Khinaligchay rivers differs from the zonal value by 46-97%.[6]

Although rivers of Group 4 and Group 3 are similar in terms of feeding and flow regime, the position of the basins plays an important role in their separate grouping.

Moreover, considering the natural conditions of the area, it is possible to determine the flow effect of landscape differentiation in the vertical direction, the water consumption, and the flow module within the landscape zone of each river. During the calculations, the average height value of the area covered by the landscape types was used (Table 3).

It should be mentioned that only the Atachay passes through the semi-desert landscape of the sharply and moderately fragmented foothills among the rivers of the study area. This landscape type covers altitudes of 500-1500 m. At an average height in this landscape, the water discharge of the Atachay River is 0.06 m^3/s, and the flow volume is equal to 1.98 million m^3.

As indicated in Table 3 the river flow decreases as the altitude rises across the landscapes. Of course, the impact of physical and geographical factors on this process is inevitable.

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[4]Imanov, F.A. Water resources of East Azerbaijan rivers / F.A.Imanov, R.H.Verdiyev, Z.B.Agayev, Sh.Y.Humbatova. – Baku, – 2012. – 183 p.

[5]Imanov, F.A. River flow / F.A. Imanov. – Baku: BSU publishing house, – 2001. – 208 p.

[6]Aliyev, F.Sh. Use of underground waters, resources, and geoecological problems of the Republic of Azerbaijan / F.Sh. Aliyev. – Baku: Elm, – 2000. – 326 p.

Table 3

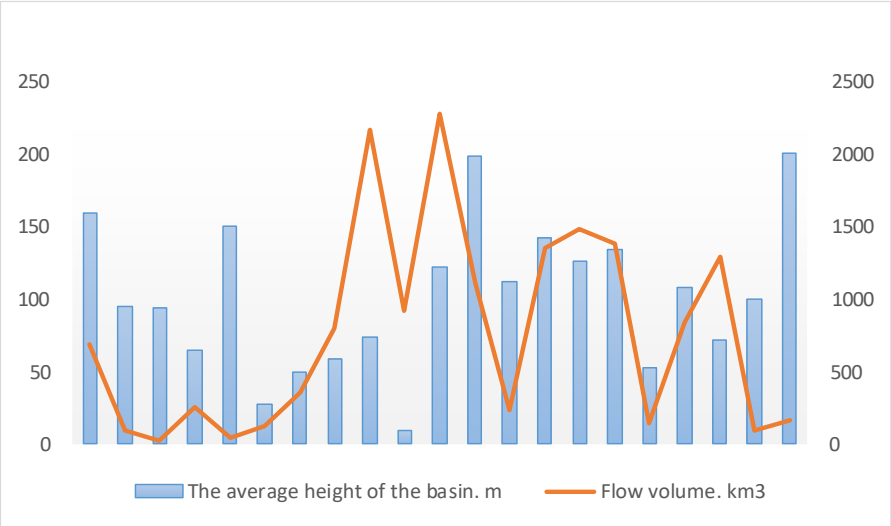
Calculated discharge and flows for landscape complexes

Landscape type	Altitude, m	River Group							
		Discharge, Q, m^3/s				Flow, W, mln m^3			
		Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4
Meadow-forest landscape and semi-desert landscape of plains and lowlands	0-100	8.97	4.42	2.32	-	282.66	139.27	72.98	-
		57%	28%	15%	-				
Arid forest-shrub landscape of intensely fragmented foothills	100-500	8.37	4.08	1.96	0.49	263.76	128.56	61.64	15.35
		56%	27%	13%	3%				
Moderately fragmented lowland broadleaf forest landscape	500-1000	6.87	3.23	1.06	0.24	216.51	101.78	33.29	7.47
		60%	28%	9%	2%				
Broad-leaved forest and post-forest forest-shrub landscape of sharply fragmented mid-mountain and semi-desert landscape of foothills	1000-1500	5.37	2.38	0.16	-	169.26	75.01	4.94	-
		68%	30%	2%	-				
Alpine, subalpine meadows and meadow-steppe landscape of intensively fragmented highlands	1500-2500	3.12	1.11	-	-	98.38	34.85		-
		74%	26%	-	-				
Nival, partially nival-glacial and subnival landscape of intensively fragmented highlands	2500- >	1.62	0.26	-	-	51.13	8.07	-	-
		86%	14%	-	-				

The highest water discharge corresponds to the headland-semi-desert landscapes, and the lowest water discharge corresponds to the source - alpine, subalpine meadows. The average indicator of water discharge covers an altitude of 1000-1500 meters. This also applies to broad-leaved forest landscapes.

61% of the water discharge in the area belongs to the Group 1, 28% to the Group 2, and 10% to the Group 3 rivers. The share of Group 4 rivers in water discharge makes 1%.

In this connection, a graph of the relationship between the average years-long flow and the average height of the basin was constructed to determine the influence of the relief on the flow in the research work, based on the observation data of the rivers (Graph 1).



Graph 1. Relationship between flow and mean height

The analysis of the relationship shows that the change of the flow towards the height is different due to the impact of physical and geographical factors. The increase of the current towards the height is felt more clearly. That is, the rocks that make up the river basins have

a good drainage capacity, and more precipitation falls here compared to other areas. A weak increase in the flow due to the height is found in the lower parts of the rivers.

Heavy rainfall in the middle mountainous zone of the area has led to the development of a maximum river network. In higher zones, the reduction of the river network depends on the lack of precipitation and physical-geographical conditions. The change in the river flow is caused by the change in the amount of precipitation and evaporation in the area.[7]

The flow elements formed in the basin change as the climate elements change depending on the terrain, the direction of the slopes, and the height of the basin. The water regime of rivers also changes, and maximum-minimum flow phases are formed following the change in the role of river feeding sources throughout the year. This year-round change complicates the issue of using water resources.

One of the main reasons for the diversity of the relationship between the annual flow and the average height of the basin is the presence of Tertiary mountains on the northeastern slope of the Greater Caucasus. Although precipitation positively affects runoff in these areas evaporation has the opposite effect.

Forests belonging to our study area have great soil-protection and water-regulating importance. These forests are very complex and diverse in terms of their composition and have different types of trees and shrubs. The upper margin of forests in the Greater Caucasus is 2000-2500 meters high.

The soil-vegetation cover on the northeastern slope of the Greater Caucasus is subject to the law of vertical zonation. Thus, the soil types towards the height in the area replace each other according to the law of zonation. Depending on the quality of the soil cover, rivers are fed more by groundwater. The effect of land cover on flow can be seen in the flow cones of rivers.

The study area's rivers are in the Guba, Gusar, Khachmaz, Shabran, and Siyazan administrative regions. These regions have

[7]Mahmudov, R. Modern climate changes and dangerous hydrometeorological phenomena / R. Mahmudov. – Baku, – 2018.

intensively developed agricultural fields.

According to the information from the State Statistics Committee of Azerbaijan, the diversity in the amount of water from natural water sources and water use indicators in the regions of the North-Eastern Slope of the Greater Caucasus are noticeable in 2018-2022 (Table 4).

Table 4
Use of water sources in the northeastern administrative regions of the Greater Caucasus

Water taken and used (million cubic m.)	Year	Guba	Gusar	Khachmaz	Shabran	Siyazan
Water taken from natural sources	2018	67.7	737.7	117.6	-	0.3
	2019	75.7	641.6	165.0	-	0.3
	2020	84.7	714.7	146.7	0.1	10.6
	2021	82.7	759.8	134.5	0.1	10.8
	2022	89.8	679.1	171.7	2.9	10.8
Water consumption	2018	67.2	57.5	144.4	53.4	17
	2019	62.6	59.6	152.9	57.4	20.2
	2020	67.6	65.4	113.0	37.6	19.6
	2021	68.8	69.1	164.3	32.2	16.4
	2022	72.21	71.4	167.5	432.5	17.16
Water loss	2018	22.8	65.4	59.9	8.3	5.3
	2019	24.2	87.9	60.1	7.8	8
	2020	82.7	26.1	43.2	4.7	4.6
	2021	25.6	86.4	43.7	4.6	4.4
	2022	25.7	35.2	64.1	8.3	4.4

Thus, the amount of water from natural sources in the last five years in the Guba district increased to 89.8 mln. m^3. Compared to the consumed water, the water waste has increased by 25%. Unlike Guba, the water waste is less than the water consumed in the Gusar district. The amount of water from natural sources also decreased to 679.1 m^3.

The Shabran district showed a sharp increase in the amount of water from natural sources and water consumption.

The observed increase in the amount of water taken from natural sources and at the same time in the amount of water used in the Khachmaz region is also reflected in water loss.

As the figures show, natural resources are used intensively every

year in the study area. The water sources of the population living around the Gusarchay-Gudyalchay basin are focused on agriculture. Consequently excessive use of river waters affects the regular flow regime of rivers.

Almost all the studied rivers in the area have been subjected to anthropogenic loading. he quality of the river's flow is affected by the wastewater discharged from the settlements, the collection of sand and gravel from the channel, and recreation areas, etc., built on the banks.

While rising to the altitude in the area, the ecological condition of the rivers is defined as highly polluted, polluted, partially polluted and conditionally clean. Since the rivers are widely used some of them do not have water in their downstream channel. This threatens the existence of rivers as a natural landscape component and water source. If this situation continues to intensify, it may hamper water use in the future.

The increase in the role of anthropogenic factors in river basins with the implementation of various water management measures requires a comprehensive study of the changes that have occurred in the hydrological regime of the stream and will occur in the future. It is impossible to effectively use the water resources of the area and properly direct economic activity without studying all these factors.

The third chapter is titled "**Analysis of the structure of the river network of the northeastern slope of the Greater Caucasus**". The chapter analyses the river network, the dependence of flow formation on natural factors and the morphometric characteristics of river basins.

The analysis has revealed more clearly the diversity in the rivers' morphometric indicators (Table 5).

Based on the results obtained following the research, the distribution of the hydrological observation points located in the area based on the area and height of the basins was considered. It has revealed an uneven distribution of the stations.

Table 5

Morphometric indicators of the rivers of the northeastern slope of the Greater Caucasus

№	Rivers	River length, km	Basin area, km^2	The length of the river network, km	The density of the river network, km/km^2	The altitude of the river source, m	Average height of the basin, m
1	Agchay	59.7	242	162.4	0.671	2383	846
2	Atachay	49.2	420.3	229.5	0.546	2058	1073
3	Cagajigchay	68.1	275.6	187.4	0.680	1790	1053
4	Devachichay	44.6	446.8	143.2	0.321	1648	795
5	Ganarchay	28.4	175.3	118.9	0.678	2518	1397
6	Gilchay	20.8	119.5	53.3	0.446	1602	1021
7	Gilgilchay	69.6	967.1	451.8	0.467	2384	1301
8	Guruchay	69.7	346.8	134	0.386	2525	1491
9	Garachay	91	404	191	0.473	3587	1800
10	Gudyalchay	100.7	755	335.2	0.444	3648	2039
11	Gusarchay	96.6	652.7	274.8	0.421	4400	2202
12	Shabranchay	50	225.6	155.2	0.688	1783	913
13	Tahirchal	32.8	248.3	95.4	0.384	4224	2379
14	Valvalacay	90.3	770.2	321.3	0.417	3455	1763
Total		871.5	6049.2	2853.4	7.022	-	-

The average amount of river network density on the rivers of the northeastern slope of the Greater Caucasus varies from 0.69 km/km^2 to 0.32 km/km^2 from north to south. The high amount of atmospheric precipitation has caused the development of the maximum river network in these areas.

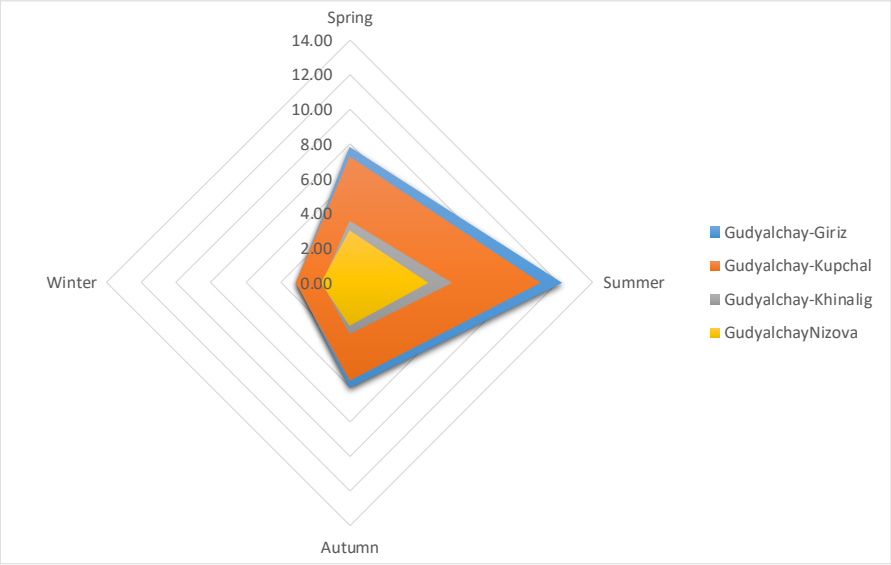
The decrease in the density of the river network in the higher areas stems from less precipitation and more rocks. In the low mountainous areas, the reduction of precipitation and water loss by absorption into alluvial sediments have an important effect. As a result the change in physical and geographical conditions on the heights has an impact on the development of the river network and the density of the river network changes. This, in turn, determines the formation of the river flow and its uneven distribution on the territory.

It was determined by the analysis of the stationary observations made on the rivers of the area that although observations were made in 21 stations of 14 rivers, their frequency varies widely. Valvalachay-Tangaalti station (1928-2022) which has the longest series of water consumption, was taken as an analogue, and the consumption series of short-ranked river stations were extended and brought to the same period of 94 years. The extension of the rows was performed based on the relationship between the average monthly water consumption of parallel years. Flow quantities of rivers without hydrological stations were calculated based on the similarity method. Based on the extended series, the multi-year average water consumption for the stations was calculated.

The study determined the differences in the years of observation for the stations in the area. At present, some of these stations are operating as well. Very few stations are currently operating based on modern technology. In many locations Gusarchay-Kuzun, Guruchay-Susay, Gudiyalchay-Kupchal, Garachay-Ruk, Chaghajigchay-Rustov, Valvalachay-Nohurduzu the latest observation data refer to 5-6 years ago (2016-2018). This shows that the observation points do not continue to operate.

The water consumption of rivers varies according to the seasons, depending on the altitude. It is directly related to the diet and consumption of these teas. This can be clearly seen from the seasonal distribution of the average value of water consumption in four observation points located

at different heights above Gudyalchay - Gudyalchay-Giriz, Gudyalchay-Kupchal, Gudyalchay-Khinalig, and Gudyalchay-Nizova. As can be seen from Figure 2, the lowest price of water consumption is observed in the Nizova district. The distribution of water consumption by seasons is almost the same in all the stations located on the river. In all four locations, the highest rate of water consumption occurs in the summer season (41%) and the lowest rate in the winter season (12%) (Graph 2).



Graph 2. Seasonal distribution of water consumption in Gudyalchay

The study used a 1:100000 scale map of the area to analyze the structure of the river network. On the map, the degrees of the rivers in the catchments of all the basins are determined according to the Horton-Strahler classification. The study revealed that all other rivers, except Ganarchay, Gilchay and Tahirchal rivers, belong to the fourth-class rivers. The mentioned rivers belong to the third-order rivers.

At the next stage, it became clear from the relationship between the number and average length of rivers of different orders and their degrees that as the orders of rivers increase, their number decreases, while their

average length, on the contrary, increases.[8]

The values of various hydrographic indicators were analysed according to the orders of the rivers in the area. It was found that the maximum value of the total number of river orders included in the research area is in the Gilgilchay basin (N=222). The maximum frequency of river lengths was recorded in the Chaghajigchay basin (Fs=0.48). The maximum density of the river network is observed in the Shabranchay basin (0.69 km/km^2).

During the research, the shape index of territorial rivers was calculated based on the influence of the shape of river basins on geomorphometric development. Basin shape (R_f) helps determine whether a river basin is circular or elongated. By calculating the form indices (R_f) of the river basins, it became clear that in the rivers with a low value of Rf, the flow is connected to the main branch by a small amount from the side branches for a short period of time, and a long-term flow is expected in the main branch. However, the exact opposite is observed in the basins with a higher R_f value. The flow from the side tributaries joins the main branch, and a short-term flow is observed in the main branch. This formula can provide information about the basins' shape and flow characteristics. River basins with a low value of the basin shape index are elongated, while basins with a higher value have a circular shape.

$$R_f = \frac{\mathrm{A}}{L^2}$$

Here R_f – is the basin shape; A - river basin area, km^2; L - river length, km.

This chapter has also investigated the influence of landscape differentiation on river flow in the example of Gusarchay and Gudyalchay basins, which are the most abundant rivers in the area.

The Gusarchay-Gudyalchay basins with an area of 132,226 hectares are bordered by the Samurchay basin to the north, the Caspian Sea to the east, the Karachay basin to the south, and Gabala and Ismayilli districts to the west. The 98.6-km-long Gusarchay River takes its beginning from

[8]Abdurakhmanova, G.J. Analysis of morphometric indicators of rivers of the north-eastern slopes of the Greater Caucasus (within Azerbaijan) // Astrakhan Bulletin of Environmental Education. - 2020, - p. 45-54

the 3780-meter-high Bazarduzu mountain, passes through the territory of the Gusar, Guba, and Khachmaz districts, and flows into the Caspian Sea.

7% of the river's annual flow comes from rain, 64% from snow, and 29% from groundwater. 19% of the flow passes in spring, 56% in summer, 18% in autumn, and 7% in winter[9]. The area of the river basin totals 68369 hectares. Snow (40%) and underground water (45%) make the main part of the river feeding.[10]

The longest observation in the Gudyalchay River was occasionally carried out in Kupchal station in 1933-2015 and in Gusarchay in Kuzun station occasionally in 1930-2015. Consequently, a connection was established for parallel years in other stations based on the average monthly water consumption data recorded in the Kupchal and Kuzun stations. Based on the extended series, the average water consumption for the stations was calculated over the years.

It was found that the area altitude has a significant influence on the water balance of the river basin. In the upper parts of the basins, precipitation accumulates in the form of rain, and in the summer months it melts, feeding the rivers.

The research calculated the area and length of the Gudyalchay and Gusarchay basins (Table 6).

The information in the table reveals that the length of rivers and the area covered by the basin are different in different landscapes.[11] This difference causes the river's flow indicators to change. The water consumption of rivers decreases, going higher in the landscapes. Undoubtedly, the impact of physical and geographical factors on this process is inevitable.

One of these effects is relief features. The height of the area affects the water balance of the river basin. At the top of the basins, precipitation accumulates in the form of sediments and melts in the summer, feeding

[9]Imanov, F.A., Water resources of East Azerbaijan rivers / F.A. Imanov, R.H. Verdiyev, Z.B. Aghayev, Sh.Y. Khumbatova. - Baku, - 2012, -183 p.

[10]Rustamov, S.H. Rivers of the Azerbaijan SSR and their hydrological characteristics / S.H. Rustamov. - Baku: Azerbaijan EA publication, - 1960 - 194 p.

[11]Abdurakhmanova, G.J. The influence of altitudinal differentiation of landscapes on river flow (On the example of the north-eastern slope of the Greater Caucasus) // Vestnik VSU. Series: Geography. Geoecology, - 2019, No. 3. - p. 40-49

the rivers.

The rivers belonging to the Gusarchay-Gudyalchay basin flow from the north-west to the south-east. The formation and development of the erosion process in rivers depend on the relief of the area, as well as the inclination of the slopes, their height, their distance, and the shape of the surface structure of the slopes.

Table 6
Area and length of Gudyalchay and Gusarchay basins by landscape types

Landscape types	River basin (ha)		River lenght (km)	
	Gudyalchay	Gusarchay	Gudyalchay	Gusarchay
Intensely fragmented high-altitude nival, partially nival-glacial landscapes	6386	10425	13,8	14,6
Intensively fragmented high-alpine alpine, subalpine meadows and meadow-steppe landscapes	27727	9528	43,3	10,5
Broad-leaved forest and post-forest meadow-shrub landscapes of sharply fragmented midland	8030	12159	13,6	17,5
Moderately fragmented lowland broadleaf forest landscapes	6604	4335	18,9	18,4
Arid forest-shrub landscapes of intensively fragmented lowland	6021	9671	19,2	18
Meadow and forest-meadow landscapes of moderately fragmented lowland plains and lowlands	1717	11067	0,5	9,5
Semi-desert landscapes of moderately and poorly fragmented lowland plains and lowlands	7390	11184	20,3	10,1

As a result, the impact of landscape differentiation on the river flow

in the area is complex and varies depending on the influence of both physical, geographical, and anthropogenic factors. Due to the influence of physical and geographical factors towards the height, the water consumption of rivers decreases.

The fourth chapter of the dissertation is called "**Landscape hydrological zoning of the territory**". This chapter determines the positions of the observation points that operated and are currently operating on the northeastern slope of the Greater Caucasus by landscape types and carries out landscape-hydrological zoning of the area.

Observation points are unevenly distributed by landscape types in the study area. The landscape types surrounding the sources of rivers generally do not have hydrological stations. Most sites are located in the broad-leaved forest and post-forest forest-shrub landscape type of the middle highlands. Observation points in river basins are partially or wholly located in six different landscape types:

1. Nival, partially nival-glacial, and subnival landscapes of the highlands (2 sites);
2. Alpine, subalpine meadows, and meadow-steppe landscapes of intensively fragmented highlands (3 sites);
3. Broad-leaved forest and post-forest forest-shrub landscapes of sharply divided middle highlands (7 sites);
4. Moderately fragmented lowland broadleaf forest landscapes (4 sites);
5. Arid forest-shrub land shafts of intensively fragmented foothills (4 sites);
6. Semi-desert landscapes of sharply and moderately fragmented foothills (1 site).

Although the stations are unevenly distributed across the landscapes, the location of the stations can be considered favourable for studying the role of the landscape in the formation of the flow. Most of the rivers in the studied area belong to the fourth-order rivers. There are no monitoring stations in the third-order rivers. It is necessary to pay attention to the influence of anthropogenic factors on rivers when allocating stations. Thus it is significant to allocate observation points at the intersection of hydroelectric power plants and water junctions, in the upper and lower parts of rivers from widely irrigated areas, in the upper and lower parts of

river water intakes for water supply to population and industrial enterprises, and in places where large canals take water. The main reason is to conduct a detailed analysis of the factors affecting water flow indicators.

The zoning law was used based on the basin principle while preparing the landscape-hydrological zoning scheme of the northeastern slope of the Greater Caucasus.

Landscape types, regime characteristics of rivers, average multi-year flow, food sources of rivers, natural regulation coefficient determined by the ratio of surface flow to underground flow, and density of the river network were accepted as criteria for zoning. The study has compiled the landscape-hydrological zoning scheme of the northeastern slope of the Greater Caucasus (Map-scheme) for the first time.

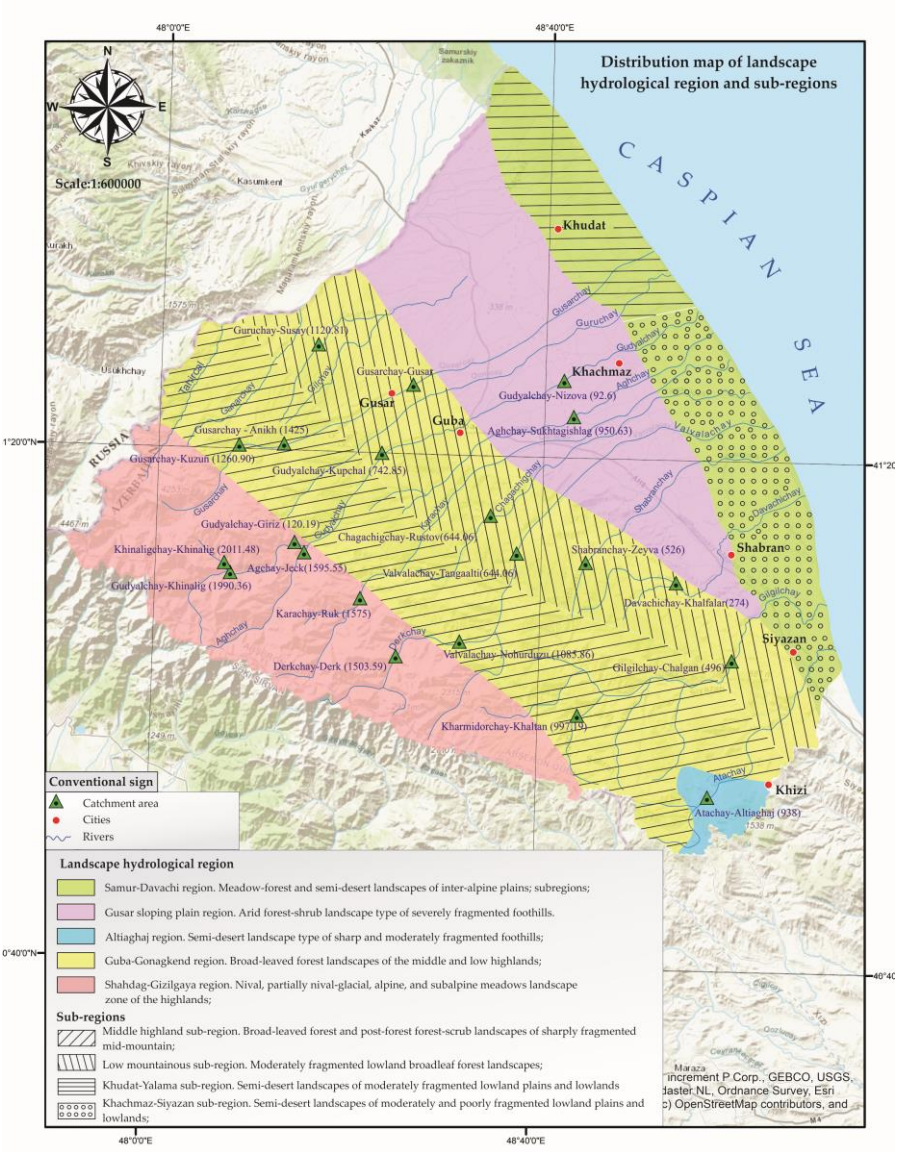
There are five landscape-hydrological regions and four sub-regions on the northeastern slope of the Greater Caucasus:[12]

I. Shahdag-Gizilgaya landscape-hydrological region. The area makes 1288.4 km^2. The region is in the nival, partially nival-glacial, alpine, and subalpine meadows landscape zone of the highlands. The area is dominated by nival, partially nival-glacial, subnival and alpine, subalpine meadows, and meadow-steppe landscape types of intensively fragmented highlands.

The main rivers of the region are Gusarchay, Gudyalchay, Garachay, and Derkchay. The study used data fron five observation stations within the region - Gudyalchay-Khinalig, Khinaligchay-Khinalig, Agchay-Jek, Derkchay-Derk, and Karachay-Ruk.

The rivers of the Shahdag-Gizilgaya landscape-hydrological region have their own regime. The main water regime phase of the rivers, taking their source from within this region, is the spring flood. The share of underground water in feeding rivers reaches 42%. The density of the river network within the region is 166.46 km/km^2.

[12] Abdurakhmanova, G.C. Flow characteristics of the rivers of the landscape-hydrological region of the northeastern slope of the Greater Caucasus // - Baku: News of the Pedagogical University, - 2021, V.69, #2, - p.56-66.



Map-scheme. Landscape-hydrological zoning of the northeastern slope of the Greater Caucasus

II. Guba-Gonagkend landscape-hydrological region. The total area of the region makes 1363.9 km^2. This region is divided into two sub-regions:

1. Middle mountainous sub-region.
2. Low mountainous sub-region.

Broad-leaved forests and post-forest meadow-shrubs landscapes of the middle highlands and partially low highlands are spread in the middle highland sub-region. A broad-leaved forest post-forest forest-shrub landscape type exists in the sharply divided middle highlands of the area. Brown forest, cold-climate broad-leaved forests with wet winters on typical brown and washed soils, and cold-climate broad-leaved forests with dry winters on brown mountain-forest soils prevail within the sub-region.

Seven hydrological stations - Gudyalchay-Giriz, Gusarchay-Kuzun, Valvalachay-Nohurduzu, Kharmidorchay-Khaltan, Gusarchay-Anikh, Gusarchay-Gusar, and Guruchay-Susay have operated in the region. The density of the river network here is 260.06 km/km^2.

3. Altiaghaj landscape-hydrological region. This landscape-hydrological region covers a minimal area of 100.2 km^2 within the northeastern slope of the Greater Caucasus. The semi-desert landscape of lowland and frontal highlands is spread in this region. The semi-desert landscape type of sharp and moderately fragmented foothills prevails in the area.

The only river flowing in the region is the Atachay River, and the data from Altiaghaj station were used in this regard. The density of the river network is 286.24 km/km^2.

4. Landscape-hydrological region of Gusar sloping plain. It covers an area of 1473.8 km^2. The arid forest-shrub landscape type of severely fragmented foothills is widespread in the district, located in the arid forest-shrub landscape of the lowland. Semi-xerophytic shrubs (predominantly blackthorn) and post-forest meadows with even rainfall distribution are widespread on washed brown post-forest soils.

The study used data from four observation stations in the region: Gudyalchay-Nizova, Agchay-Sukhtagishlag, Davachichay-Khalfalar, and Gilgilchay-Chalgan. Anthropogenic load is observed in the lower reaches of rivers. The density of the river network is 178.59 km/km^2.

5. Samur-Davachi landscape-hydrological region. This region is divided into two sub-regions: 1. Khudat-Yalama; 2. Khachmaz-Siyazan. Its area makes 1092.8 km^2.

The Khudat-Yalama landscape-hydrological sub-region has widespread meadow-forest landscapes of plains and lowlands. The area is dominated by the meadow-forest landscape type of moderately fragmented lowland plains and lowlands.

The territory of the region covers the lower reaches of the Gusarchay and Guruchay rivers. Since there is no hydrological monitoring station within the sub-region, the study could not obtain accurate information about the downstream regime of the rivers. The flow indicators of the rivers are determined based on the formulas obtained for the river groups the study has determined. The density of the river network is 83.18 km/km^2.

Khachmaz-Siyazan sub-region is located in the semi-desert landscape belt of medium and weakly fragmented plains and lowlands. The dry-desert landscape of the foothills and the swamp-meadow landscape of the lowlands prevail here.

The sub-region covers the area between Gudyalchay and Atachay, which is up to 100 meters high. The density of the river network here is 182.69 km/km^2. The most common types of surface water in the sub-region are sulfate-hydrocarbonate, hydrocarbonate-sulfate, and calcium-hydrocarbonate water.

The study used the "Landscape types of Azerbaijan" map (2014), the "Physical-geographical regionalisation of Azerbaijan" map (2014), and the "Elevation model of the northeastern slope of the Greater Caucasus" map to determine the borders of the regions.

RESULTS AND SUGGESTIONS

The main results of the dissertation work include:

1. The research determined the borders, areas, heights of the landscapes, the length, and area of the river basins in the studied area according to the landscape types using ArcGIS, establishing that their morphometric indicators were unevenly distributed across the landscapes.

2. The research defined that in the north-eastern slope of the Greater Caucasus, the observation points are not located economically according to landscape types, which makes it difficult to correctly assess and forecast the flow and water resources.

3. The analysis of the hydrological observation points on the rivers of the territory revealed that the observation points are unevenly distributed in six landscape types. A major part of the points belongs to broad-leaved forest and post-forest forest-scrub landscapes

4. To determine the impact of landscape differentiation on flow, regional rivers were divided into four groups based on the relationship established between the average height of the basin and water consumption. A constant indicator of water consumption corresponds to broad-leaved forest landscapes covering an altitude of 1000-1500 meters.

5. According to the Horton-Strahler classification, most rivers (79%) belong to the fourth-order rivers. There is a direct correlation between the rate and length of the river and an inverse correlation between the number. That is, the length increases as the order of the river increases, while the number decreases.

6. Using the mathematical expressions obtained during the grouping of rivers in the research, the quantity of water consumption at any height in the river basins within the group could be deterined.

7. Landscape-hydrological zoning of the northeastern slope of the Greater Caucasus has been conducted for the first time, considering the landscape types, regime characteristics of rivers, average multi-year flow, feeding rivers, natural regulation coefficient determined by the ratio of surface flow to underground flow, and density of the river network as the main criteria. The territory is divided into five landscape-hydrological regions and 4 sub-regions.

Based on the obtained results, the following suggestions are made:

- It is recommended to place hydrometric observation points in each of the landscape types to determine the flow indicators of the rivers;

- Activities of quarries should be regulated by normative documents to prevent the lowering of the riverbed due to the transportation of sand and gravel from the channels;

- The mechanism of use should be improved to save water.

Scientific publications on dissertation topic:

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Leader Heydar Aliyev, - 2023, No.2, p.84-89.

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