EARTH SCIENCES

ASSESSMENT OF THE NATURAL REGULATİON LEVEL OF RİVERS AND THEİR RUNOFF DURİNG İNTENSİVE İRRIGATİON PERİOD

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Abstract
The article is devoted to the study of the natural regulation of rivers and the runoff during the intensive irrigation period. Since the Republic of Azerbaijan is located in an arid region, there is an acute shortage of water, and river waters constitute the main part of its water resources. However, since most of the rivers are drying up, their transit and natural regulation levels are unfavorable, the possibilities of using their water are weakened. The natural regulation of rivers refers to the favorable distribution of their runoff throughout the year. The main part of the river runoff occurs in the spring months, when the demand for water is low. During the irrigation period (summer months), when the demand for water is highest, the level drops. As a result, a serious disproportion arises between the volume of river water runoff and the possibilities of its use. The southern slope of the Greater Caucasus, which we have chosen as the study area, is the richest region in Azerbaijan with river waters. The study assessed the annual distribution of the runoff of the major rivers of this region, especially their shares in the spring and summer months. The natural regulation state of the rivers, the volume of spring runoff, and the possibilities of their accumulation for using irrigation in the summer months were assessed.

Keywords: water resources, river runoff regulation, annual runoff distribution, intensive irrigation period, spring and summer runoff.

Introduction

The Republic of Azerbaijan is among the countries with limited freshwater resources. Water resources in Azerbaijan are very small compared to other countries of the South Caucasus and account for approximately 15 percent of the water resources in the entire region. 67-70% of river water resources in Azerbaijan are formed outside our country's borders. As a result of the impact of climate change and excessive water withdrawal for use in neighboring countries, the water resources decreased by 26.4% to 26.2 billion cubic meters during 1980-2023. In addition, during this period, surface water resources entering the country's territory through transboundary rivers also decreased by 35.9% to 13.2 billion cubic meters, and local river flow decreased by 23.3% to 4.6 billion cubic meters [1].

According to the data of the State Statistical Committee of the Republic of Azerbaijan, the volume of renewable surface fresh water resources currently amounts to 26.2 billion cubic meters. Of this, 8.4 km^3 is formed from groundwater, 4.6 km3 from local river runoff and 13.2 km^3 from transboundary surface waters. 17.8 km^3 (67.9 %) of the renewable fresh water resources are formed from surface fresh water resources. If in 2000 the surface fresh water resources were 23.4 km^3, in 2023 they decreased by 24.1% to 17.8 [2].

The results of water resource projections are also not encouraging. According to recent research by the World Resources Institute (WRI), Azerbaijan ranks 59th out of 164 countries that will face water scarcity by 2050 and is classified as a country with a medium-high (20-40% water stress) risk category [3].

According to Azerbaijan's National Report to the UN Framework Convention on Climate Change, the volume of water resources (including transboundary water resources) is projected to decrease by 5-10% by 2040, 10-15% by 2070, and 10-15 and 15-25%, respectively, depending on the level of global temperature increase.

One of the most important aspects that complicates the use of water resources is the significant increase in demand for water against the background of their decline. According to the State Statistical Committee, while the volume of fresh water withdrawn from natural sources increased by 27.9% in 2001-2023, the volume of water consumed increased by 52.4%, including for irrigation and agricultural supply, almost doubled. On the other hand, the uneven distribution of river water resources throughout the year and across the territory significantly complicates their use and cannot meet the water demand that is increasing year by year.

Annual water consumption in Azerbaijan is 11-12 km^3. At the same time, serious losses occur during water distribution due to outdated infrastructure. As a result of the constantly increasing water demand of the economy and the population, an average water deficit of 4.5-7.0 km^3 occurs in Azerbaijan per year. This situation requires regulating the runoff of rivers and constructing artificial reservoirs [4-5].

Currently, in the republic, more than 60 reservoirs, each with a volume of more than 1 million m^3, can store up to 21 billion m^3 of water. However, the depletion of river water resources also has its negative effects in this area. Thus, the decrease in river water consumption reduces the volume of water entering the reservoirs, weakening their use. For example, between 2016 and 2020, the average annual flow of water entering the Mingachevir reservoir, the largest in Azerbaijan alone, decreased from 344 m^3 per second to 192 m^3, a decrease of 44.2%.

Methods and materials

The primary research materials were the observation data on climate and runoff of the Ministry of Natural Resources and Ecology of the Republic of Azerbaijan. The collection of important factors involved in the flow formation, such as elevation, slope, landscape and other components, was obtained through satellite images. From the climatic parameters, atmospheric precipitation and air temperature were preferred, and from the runoff quantities, river water discharge data was preferred. Both annual and monthly data of the mentioned hydrometeorological indicators were used for the study area. The restoration of observation series was carried out using both traditional and modern methods. The most important of the traditional methods were the Analogy and Interpolation methods [6-7].

Here, the main focus was on establishing relationship graphs between the average elevation of the basin and hydrometeorological parameters. The results of the relationships established based on the data of the observation stations were extrapolated for river basins without data. The homogeneity of the observation series and the reliability of the results obtained were checked using the Fisher and Student criteria [8-10].

The results obtained during the research process were also refined using modern scientific methods. The results obtained using modern Interpolation and Counter-Approach technologies were evaluated separately for each river basin using the ArcGIS program [11-12].

Results and discussions

The southern slope rivers of the Greater Caucasus were taken as the study area (Figure 1). This region is the richest in Azerbaijan in terms of river water resources. The right tributaries of the Kura River, the largest river in Azerbaijan, flow from here. The largest rivers of the southern slope of the Greater Caucasus are the Eyrichay, Pirsaat, Turyan, Goychay, Alijan, Girdiman, and Agsu rivers. The rivers are mainly fed by groundwater, rain, and snow. Most of the rivers are abundant in their upper reaches, but they also have a high flood risk. The river basins of the study area can be divided into two parts according to their physical and geographical characteristics and feeding regime:

1) Basins between the Mazym and Dashagıl rivers. They are distinguished by their higher water discharge and the predominance of the groundwater share in the feeding regime.

2) Basins between the Dashagıl and Sumgayit rivers. The water discharge of the rivers is low, and the share of rainwater in the feeding regime is greater.

In order to obtain meteorological indicators (precipitation and temperature) for various hydrometric stations and river basins of the southern slope of the Greater Caucasus, actual measurement data from existing meteorological stations were used.

It was shown that there is a uniform and highly correlated close relationship (R=0.96) between the average multi-year air temperature and the altitudes of the stations for the entire study area (Figure 1).

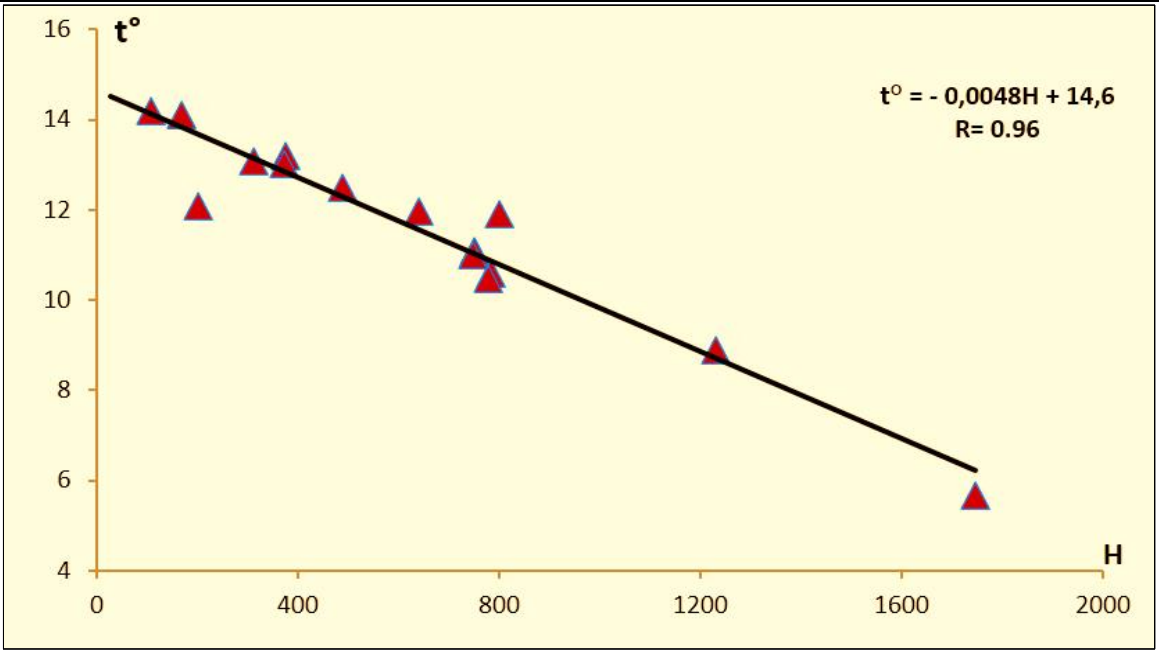

Figure 1. Relationship graph between mean multi-annual air temperature (t°) and mean altitude (H) on the southern slope of the Greater Caucasus

Unlike temperature, the relationship between atmospheric precipitation and altitude was established by dividing it into two parts due to its poor coverage for the entire study area. This division also covers two hydrologically distinct regions of the southern slope of the Greater Caucasus: within the Mazym-Dashagıl and Dashagıl-Sumgayit rivers basins (figure 2).

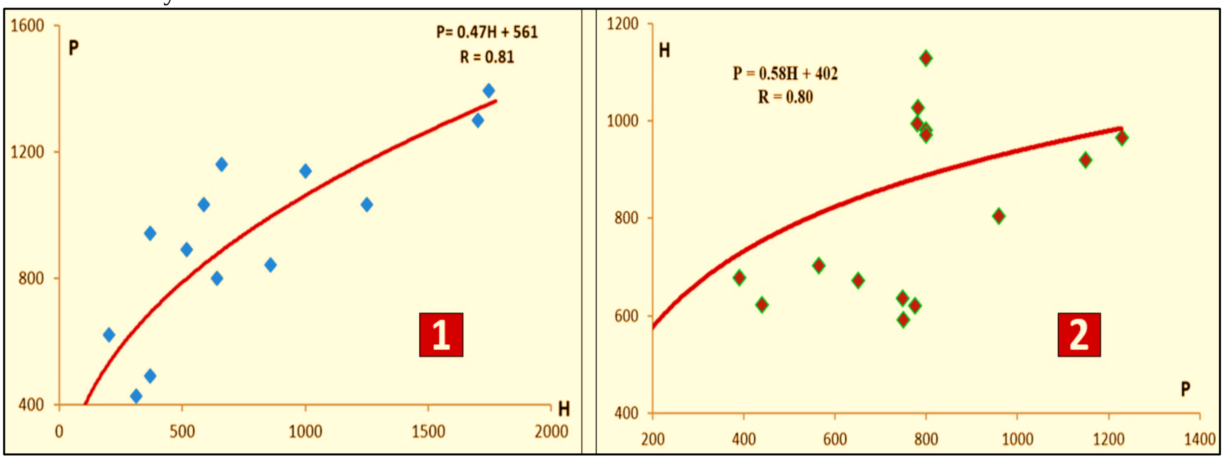

Figure 2. Relationship graphs between atmospheric precipitation (P) and mean elevation (H):
1– Between the Mazym and Dashagıl rivers. 2– Between the Dashagıl and Sumgayit rivers.

By selecting and interpolating the superior features in GIS comparison and calculation programs, average multi-year climate and flow data for spring and summer months were obtained for each river basin separately (table 1).

Table 1

Average multi-year spring and summer hydrometeorological data for river basins

Rivers	Temperature, C°		Precipitation, mm		Runoff, mm	
	Spring	Summer	Spring	Summer	Spring	Summer
Mazym	9.4	21.2	227	219	120	119
Balaken	9.1	20.8	261	242	175	160
Katekh	8.6	20.3	276	301	169	189
Tala	9.5	21.3	247	252	137	138
Mukhakh	8.2	19.8	238	262	152	181
Kapychay	9.5	21.3	172	158	67.0	64.3
Kurmukh	8.3	19.9	260	288	166	211
Kashkachay	7.1	26.5	192	173	102	89.3
Shin	6.8	18.8	201	186	120	108
Kish	7.9	19.4	228	196	145	118
Dashagıl	8.0	19.5	237	261	167	181
Kungut	8.3	19.9	252	205	130	103
Zeyzit	7.3	18.7	258	210	158	136
Eyrichay	8.6	20.3	214	198	98.5	94.4
Alijan	10.9	23.1	188	128	48.1	25.7
Turyan	9.7	21.6	262	157	73.6	74.0
Goychay	11.1	23.3	243	129	71.2	59.2
Girdiman	7.7	19.2	275	218	141	108
Agsu	10.5	22.5	226	107	46.6	26.1
Pirsaat	9.4	21.2	127	70.5	41.0	27.5
Jeyrankechmez	12.1	24.4	96.1	29.6	7.33	2.71
Sumqayıt	9.8	21.8	104	44.9	15.4	7.32

Natural regulation of river runoff is a state of more even distribution of runoff throughout the year (months and seasons). In this case, the differences in river runoff between different months and seasons are very small. Most of the rivers of Azerbaijan have a high-water regime in the spring and autumn seasons, during which 60-70% (sometimes up to 80%) of the runoff passes. At the same time, a shortage of flow is observed in the rivers in the summer and winter seasons, when the combined share of the runoff of these two seasons in the annual runoff rate can rarely reach 50%. This situation indicates that the natural regulation of the runoff in the rivers of Azerbaijan is very low. Since most of the territory of Azerbaijan is located in a dry subtropical climate, sharp differences in the intra-annual runoff regime of the rivers also limit their use and serious problems arise when using water. The main way out of the situation is artificial regulation of the river runoff. Artificial regulation of rivers is the preservation of their resources during high water use periods (especially in the summer months) by maintaining them in various water levels until the stage of low water and high use.

Currently, water resources in Azerbaijan are mostly used for agricultural purposes in the summer (intensive irrigation period) [13]. However, the driest period of rivers is precisely the summer season. In the remaining seasons, there is no big problem in this regard. Despite the fact that the winter season is also dry, it is the season when river water is used the least. Therefore, there is no need to regulate the runoff of the preceding high-water autumn season with artificial interventions. Before the summer season, the regulation of the spring season flow is inevitable. In our research, we have mainly given extensive space to the study of the runoff of the spring and summer seasons.

Previously, a sufficient amount of research has been carried out on the study of the annual distribution of the rivers runoff of Republic of Azerbaijan [14-15].

However, our research was conducted in a completely different direction and purpose. In previous studies, the priority was mainly limited to providing quantitative indicators of the annual distribution of runoff based on hydrometeorological station data. We did not limit ourselves to the distribution ofrunoff by months and seasons. Research was conducted on the runoff regime of rivers, changes in the seasonal regime against the background of climate change, the level of natural regulation, the possibilities of spring runoff for conservation in watersheds, the assessment of spring runoff reserves for the purpose of intensive irrigation periods, and other new directions.

The most serious differences in the intra-annual distribution of the runoff are manifested in the ratio of spring and summer flows. In most rivers of the southern slope of the Greater Caucasus, spring is a high-water season, and summer is a low-water season. In such a case, the highest level of regulation ("very high") was considered to be the summer runoff (Q_{sm}) higher than the spring runoff (Q_{sp}), i.e. $Q_{sm}/Q_{sp} > 1$. The values of this ratio between 0.90-1.00 were also accepted as a sufficient and "high" level of regulation. The situation where the summer runoff was less than half of the spring runoff ($Q_{sm}/Q_{sp} < 0.5$) was considered to be a very weak ("very low") regulation. In the interval Q_{sm}/Q_{sp} = 0.50-0.75, i.e., if the summer runoff was from half to 3/4 of the spring runoff, this was considered weak ("low"). Finally, a "average" regulation within the range of Q_{sm}/Q_{sp} = 0.75-0.90 was adopted. The runoff of the rivers of the southern slope of the Greater Caucasus was mapped according to the level of natural regulation (Figure 3).

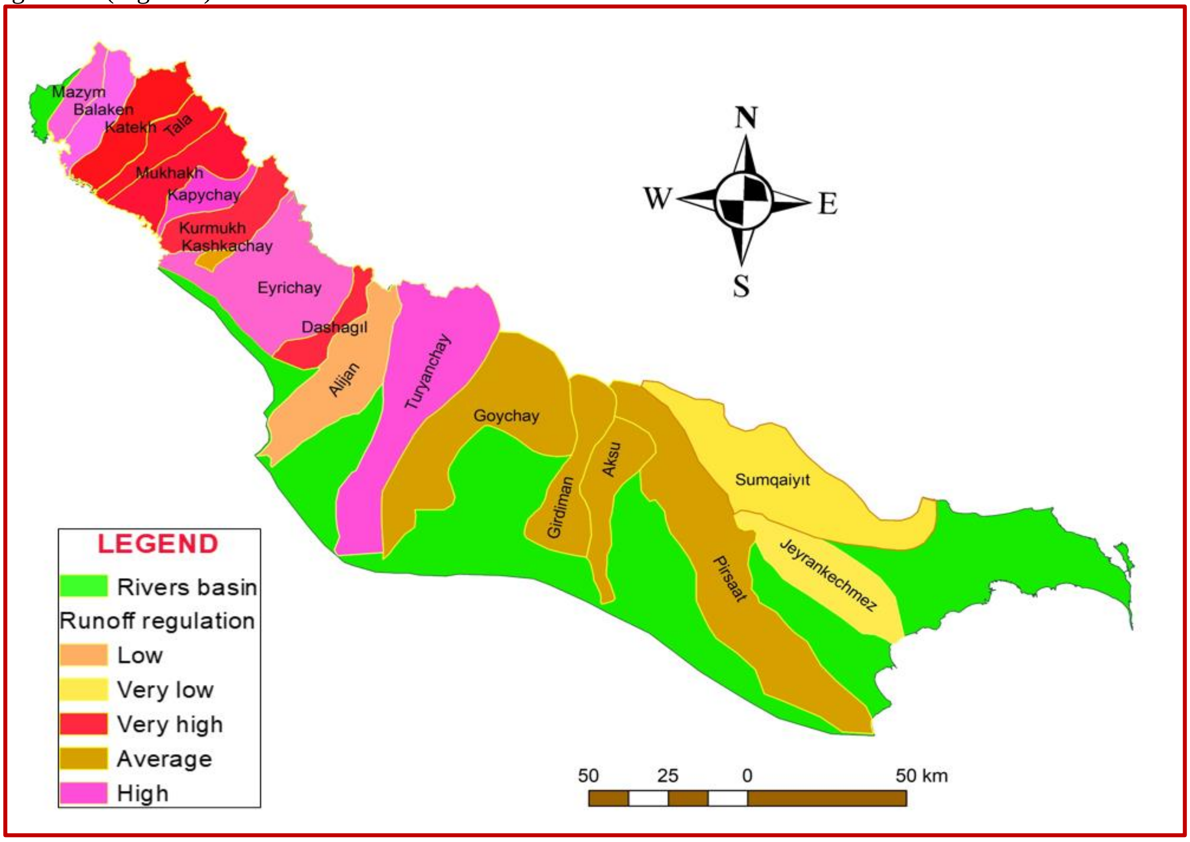

Figure 2. Natural regulation level of the rivers of the southern slope of the Greater Caucasus

The assessment of the natural regulation level of the rivers of the study area based on the ratio of summer and spring runoffs is given in the table below.

Table 2

Assessment of the natural regulation level based on the ratio of summer (Q_{sm}) and spring (Q_{sp}) runoffs

Rivers	Runoff layer, mm			Q_{sm}/Q_{sp}	Regulation level
	Perennial	Summer (Q_{sm})	Spring (Q_{sp})		
Mazym	381	119	120	0.992	High
Balaken	532	160	175	0.914	High
Katekh	548	189	169	1.118	Very high
Tala	429	138	137	1.007	Very high
Mukhakh	511	181	152	1.191	Very high
Kapychay	210	64.3	67.0	0.959	High
Kurmukh	561	201	166	1.211	Very high
Kashkachay	308	89.3	102	0.875	Average
Shin	366	108	120	0.900	High
Kish	426	118	145	0.814	Average
Dashagıl	577	181	167	1.084	Very high
Kungut	379	103	130	0.792	Average
Zeyzit	473	136	158	0.861	Average
Eyrichay	366	94.4	98.5	0.958	High
Alijan	136	25.7	48.1	0.534	Aşağı
Turyan	251	69.2	73.6	0.940	High
Goychay	213	59.2	71.2	0.831	Average
Girdiman	357	108	141	0.766	Average
Agsu	116	26.1	46.6	0.560	Average
Pirsaat	93.8	27.5	41.0	0.671	Average
Jeyrankechmez	15.4	2.71	7.33	0.369	Very low
Sumqayıt	32.5	7.32	15.4	0.475	Very low

As can be seen from Table 2, the natural regulation of rivers flowing from the western part of the study area (between the Mazym and Dashagil rivers) is better. The level of natural regulation in most rivers falls into the “high” and “very high” categories. The main reason for this is the high share of underground flow in the feeding of rivers. Due to the gradual and even distribution of the runoff in rivers fed by underground, they have better regulation, with high water discharge continuing until the summer months. Another advantage of rivers located between the Mazym and Dashagıl basins is that the average multi-year runoff share itself is also high. High annual runoff and partially good regulation allow for more rational use of the waters of the rivers located here.

The level of runoff regulation in rivers located in the eastern part of the study area (between the Dashagıl and Sumgayıt rivers) is low. This is explained by the high share of rainwater in the feeding of rivers. Both the low average annual runoff volume and the fact that the bulk of the runoff occurs during the spring rains have led to poor runoff regulation in most of the rivers located in the eastern part of this study area. Therefore, acute water shortages are observed during the period of intensive irrigation.

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