

ENGINEERING SCIENCES

QUANTITATIVE ASSESSMENT OF HYDROPOWER POTENTIAL BY THE IMPACTS OF CLIMATE TRANSFORMATION ON THE EXAMPLE OF THE RIVERS OF GEORGIA

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DOI: https://doi.org/10.31435/rsglobal_ws/31102019/6712

ARTICLE INFO

Received: 13 August 2019
Accepted: 20 October 2019
Published: 31 October 2019

KEYWORDS

Hydropower,
Hydropower resources,
Climate change,
Hydrology,
River.

ABSTRACT

The purpose of the work is the quantitative assessment of the impact of climate change on the runoff of the rivers of Georgia and, consequently, on their hydropower potential. To this end, the sections of 19 river basins located in six regions of Georgia, where natural runoff is maintained, have been reviewed – it is not regulated. The results of the study confirm the change of the water content of the selected rivers and hence their hydro-energy potential, which is related to the climate transformation process.

Citation: Grigol Khelidze, Lena Shatakishvili, Bachana Pipia. (2019) Quantitative Assessment of Hydropower Potential by the Impacts of Climate Transformation on the Example of the Rivers of Georgia. *World Science*. 10(50), Vol.1. doi: 10.31435/rsglobal_ws/31102019/6712

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Introduction. Hydropower resources occupy the dominant position among Georgia's natural resources. About 26,000 rivers flow across the country, with a total length of about 60,000 kilometers. Development of hydropower is considered as a priority for the development of the country's energy sector.

There are about 90 hydropower plants in the country, which generate more than 80% of the electricity in Georgia. As of 2018, annual electricity generation through hydropower plants is about 9.9 billion kWh [1], of which 6.5% comes from small power plants [2].

Signs of climate change in Georgia have been evident since the 1970s. Signs of climate change vary by region as well. Trends of climate change in 1955-1970 and 1990-2005 have been examined in Georgia's Second National Communication [3] of the United Nations Framework Convention on Climate Change (UNFCCC). During these periods, average temperature in western Georgia increased by about 0.2°C and yearly atmospheric precipitation decreased by 27 mm. As for eastern Georgia, average annual temperature increased by almost 0.3°C, and yearly atmospheric precipitation increased by 41 mm (Fig. 1).

It should be noted that the parameters characterized for climate change, accepted for Georgia as a whole do not sometimes coincide the results obtained locally in a particular region. An example of this is that the change of the yearly atmospheric precipitation totals in western Georgia is characterized by a declining trend, while in some areas of western Georgia (eg Lentekhi) there is a rising trend [4, 5].

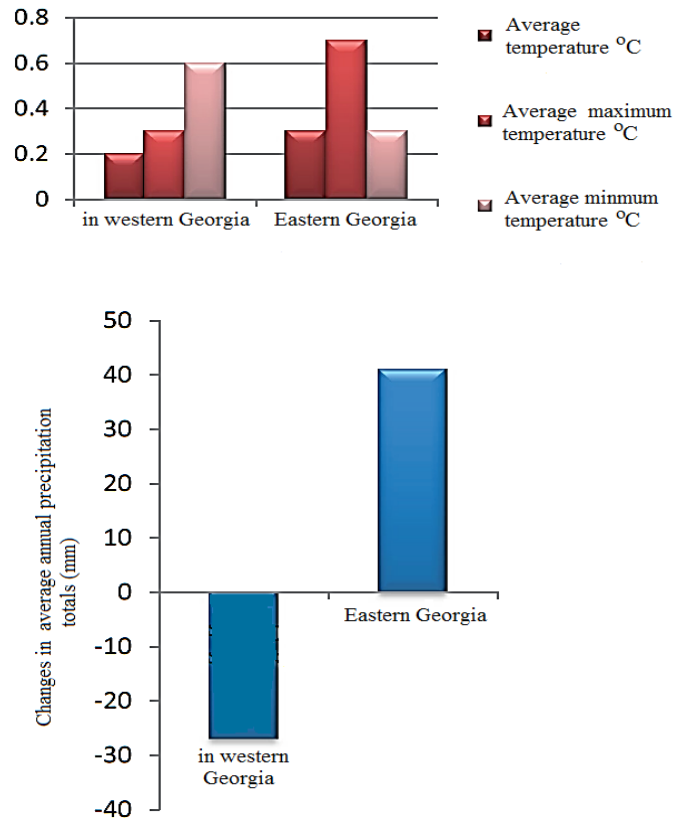


Fig. 1. Change of average temperature and atmospheric precipitation between the mean value before 1960 and the mean value for the period of 1957-2006

It should be noted that since the 1980s, the intensity of changes in both air temperature and atmospheric precipitation has especially increased. Georgia's Second National Communication about the UN Framework Convention on Climate Change also predicts changes in both seasonal and annual precipitation totals in Georgia by 2100 (Fig. 2).

The impact of climate evolution on the glacier melting process must be noted when discussing water content of the rivers of Georgia. Since the 1970s, the number of glaciers in Georgia has decreased by 13% and the area by 30% [6]. The main reason for the decrease of glacier areas is the decline of the amount of solid precipitation (snow) and the increase of average temperature. It can be argued that the decrease (melting) of glacier area is one of the main indicators of global warming. The impact of predicted climate change on the glaciers of the Enguri River Basin and consequently, on Enguri river runoff have been reviewed and analyzed in the Third National Communication of Georgia to the UN Framework Convention on Climate Change [7].

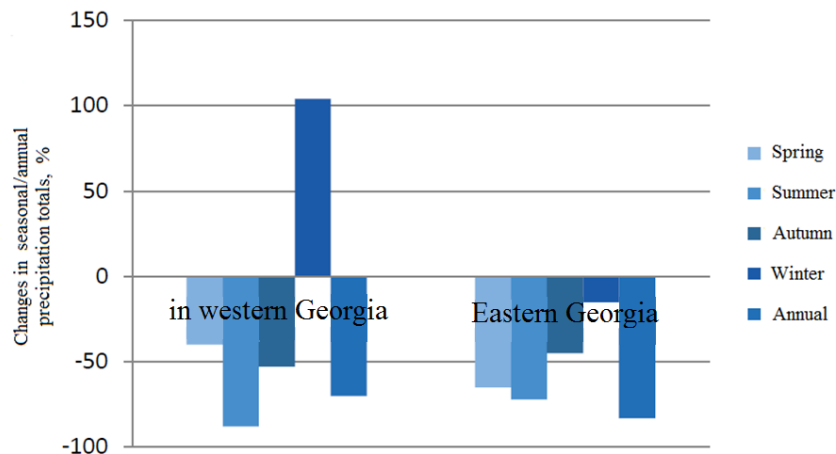


Fig. 2. Change in precipitation totals by 2100

Given all of the above, it is likely that the climate factor would affect the feeding regime and runoff of rivers in different regions of Georgia. For a quantitative assessment of such impact, it is necessary to know the characteristic parameters of river runoff (water flow), which provide information on the hydrological observation data of water flow of the study river.

Purpose of the study. The impact of climate factors on the quantitative changes in the rivers of Georgia is less studied. As for the rivers' hydropower potential, it is calculated for the rivers of Georgia based on hydrological data from the 1970s and 1980s of the 20th century [8] and does not give a complete idea of the actual hydro resource.

In order to calculate theoretical hydropower resources, it is necessary to have information on the pressure along the entire river and water consumption. Accordingly, there are several methods of calculating the hydropower potential according to the type of information available.

The following methods are used to calculate potential resources of rivers:

1. Power is depended on the length of a study area of watercourse or the fall thereof, which allows for linear or zonal counting of river resources;
2. Power is depended on the area of the basin;
3. Power is depended on the volume of the pool.

From these methods [9], the method of linear calculation of water flow capacity is the most widespread method, according to which the potential resources of a river section can be characterized by capacity and energy as follows:

$$N_{\text{Distr.}} = 9,81 \int_{H_1}^{H_2} Q_i \cdot dH, \text{ kW} \quad (1)$$

$$\mathfrak{E}_{\text{Distr.}} = \frac{1}{367} \int_{H_1}^{H_2} W_i \cdot dH, \text{ kW} \quad (2)$$

Wherein H_1 and H_2 represent water levels at the beginning and end of the site to be examined;

Q_i and W_i – total river flow and average annual runoff, respectively.

The values contained in these formulas are easily determined for the initial hydrological information, orographic characteristics of the river and time interval required. These values are available from state water cadastre and topographic maps, which are distinguished by their high reliability. Therefore, our choice was also based on the linear metering method, but we also took into account that the hydropower potential of the main rivers of Georgia mentioned above are calculated by these methods [8].

The replenishment of water reserves in the river is due to the type of water supply. In compliance with Georgia's natural-climatic conditions, all types of river feeding are presented: glaciers, snow, rains, groundwaters, however, under certain conditions (at the given river section) their proportion varies - the dominant species are one, two or rarely, three. The dominant type of river feeding is usually determined by the average height of the catchment basin, which varies across the rivers of Georgia [10].

Research results. In order to carry out quantitative assessment of the impact of climate change to river runoff and the energy potential, based on the hydrological data, we discussed 19 sections of the river located at the 6 regions distinguished by the different topographical, geological, climatic characteristics, where natural runoff is preserved - it is not subjected to regulation.

Calculations of the hydropower potential of the rivers were carried out in the following order:

1. Average annual water flow values of the study rivers [11] (in timetable) were found in the sections where natural runoff is maintained;

2. Average annual water flow of the river was determined for which the parameters for the representation of the average annual water flow range were determined, namely the relative mean square error ε_{Q_0} of the mean annual value and the relative mean square error ε_{C_0} of variation coefficient. According to the requirements of the building standards and regulations in force in Georgia, each of them should not exceed $\varepsilon_{Q_0} \leq 5\%$ and $\varepsilon_{C_0} \leq 15\%$ respectively [12, 13]. This requirement is met for all the rivers to be studied.

3. The energy potential of the rivers to be studied for the relevant crossings was calculated. The results of the calculations are given in Table 1.

Table 1.

#	River	Section, H/S	Type of feeding by ranked fraction	Catchment area, km ² / average height of the basin, m	Average annual water discharge, m ³ /sec		Difference, %	Hydropower potential of the river, MW		Difference, %
					[7]	Authors		Authors	[7]	
1	2	3	4	5	6	7	8	9	10	11
1	Samkuris-Tskali	Kadori	Snow, ground waters, rain	119,4/2590	6,81	5,64	17,2 ↓	58,75	71,6	18 ↓
2	Alazani	Shakriani	Ground waters, rain, snow	2202/1250	45,5	43,4	4,6 ↓	73,15	132,8	45 ↓
3	Ilto	Sabue	Ground waters, rain, snow	308/1250	5,44	5,1	6,26 ↓	20,68	33,6	38 ↓
4	Stori	Lechuri	Ground waters, snow, rain	211,8/1840	8,7	8,02	7,82 ↓	37,6	53,7	30 ↓
5	Adjaris Tskali	Khulo	Rain, snow, ground waters	251/1600	8,54	8,26	3,28 ↓	28,23	31,4	10 ↓
6	Chirukhis-Tskali	Shuakhevi	Rain, snow, ground waters	328/1700	11,6	9,9	14,7 ↓	50,52	64,8	22 ↓
7	Kvirila	Zestaponi	Rain, snow ground waters	2410/950	62,65	59,8	4,55 ↓	109	126,8	14 ↓
8	Khanistskali	Bagdati	Rain, ground waters, snow	658/1460	17,1	15,9	7,02 ↓	42,63	47,3	10 ↓
9	Nenskra	Lakhami	Snow, ground waters, glacier, rain	458/2270	27,9	30,3	8,6 ↑	240,1	224	7,2 ↑
10	Mestia-chala	Mestia	Glacier, ground waters, rain, snow	163,2/2750	8,24	12,8	55,3 ↑	26,3	16,4	60 ↑
11	Nakra	Naki	Glacier, ground waters, rain, snow	128,2/2520	8,72	11,4	30,7 ↑	76,4	60	27 ↑
12	Enguri	Skormeti	Snow, ground waters, glacier, Rain	2800/2310	132	118	10,6 ↓	557	629,5	12 ↓

Continuation of table 1.

1	2	3	4	5	6	7	8	9	10	11
13	Abasha	To Tekhura river outfall	Rain, ground waters, snow	350/380	14	11,9	15 ↓	30,65	45,7	33 ↓
14	Kasleti	To Tkheishi river outfall	Snow rain, ground waters	75,1/2210	3,56	4,47	20 ↓	45,23	59,6	24,1 ↓
15	Magana	To Enguri river outfall	Snow, rain, ground waters	146,8/1650	9,98	8,08	19 ↓	58	71,5	18,8 ↓
16	Tekhuri	To Rioni river outfall	Rain, ground waters, snow	1031/760	51,55	43,7	15,2 ↓	135,7	211,5	35,8 ↓
17	Natanebi	Vakijvari	Rain, ground waters, snow	80/1670	5,03	4,7	6,56 ↓	42,8	48,7	12,1 ↓
18	Baramidzistskali	To Supsa river outfall	Rain, Ground waters, Snow	74/1610	3,63	3,2	11,8 ↓	23,3	27,3	14,6 ↓
19	Rioni	Khidikari	Rain, Ground waters, Snow, Glacier	2002/1940	86,5	74,3	14,1 ↓	262,1	341,3	23,2 ↓
Total								1918,14	2297,5	16,5 ↓

The data stated in the table confirms the change of water content in the river to be studied and the hydropower potential accordingly, which is associated with the climate transformation process, namely:

Water discharges are increased mainly for the rivers that collect water from glaciers (Mestiachala, Nakra), which is explained by the intensification of glacier melting process. However, an excessive increase in water content corresponds to the higher value of the mean level of watershed. Along with the decrease of the glacier component (Nenskra), the increase in river water content decreases. The reduction of the average multi-year water consumption of the Enguri River (10.6%) and the increase of the average multi-year water consumption of the Nenskra River (8.6%) may be related to their collection structure. Fraction of collection the Enguri River from glacier is 21%, from snow - 32% as for the Nenskra River - 19.3% and 40.2% respectively, that is to say, the increase of the snow component and the fact that the tributaries of the Enguri River at the study area are predominantly fed by snow water have reduced its water consumption. As for the Rioni River, in the feeding of which portion of the glacier is only 5.6% and its tributaries are not distinguished by glacier collection at the section, may be explained by a reduction of water consumption:

The average multi-year water discharges of those rivers, dominant type of feeding of which is the melted snow waters (Samkuristskali, Magana, Kasleti) are reduced in the sections to be examined by virtually equal intensity, which is to be explained by the absence of rough winters (reduced precipitation) in recent decades:

The trend of declining average multi-year water consumption is characteristic for the rivers, main source of water collection of which is rains (Adjaristskali, Chirukhistskali, Kvirila, Khanistskali, Abasha, Tekhuri, Natanebi, Baramidzistskali, Rioni). The catchments of these rivers are located in western Georgia and the reduction of their water content is caused by atmospheric precipitation.

Water content of mainly groundwater-fed rivers (Stori, Ilto, Alazani) is reduced, which is explained by the fact that the total fraction of sediments of the main contributing factors of groundwater to all three rivers - snow and rain is close to each other.

Conclusions. Thus, calculations performed by well-established methods in international practice have determined the average multi-year water discharges of the rivers selected in accordance with the above principle, based on hydrological observations currently available at the National Environment Agency of Georgia [11]. Water discharges obtained from the calculations are substantially different from those before 1980, confirming the impact of climate change on their water content. According to the calculated water discharges and on the basis of the methodology of calculation of the hydropower potential, the hydropower potential in the selected river sections to be examined was calculated, which differs from the currently accepted for calculation. The change in hydropower potential value for the selected rivers indicates that it may change for other rivers as well. Therefore, the issue of specifying the hydro power potential of the Georgian rivers is on the agenda.

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