Changes in Runoff During the Growing Season in the Upper Reaches of the Naryn River in the Context of Global Climate Change

R. T. Akmatov[1(✉)], O. A. Karymshakov[1], Zh. O. Karamoldoev[2], and T. M. Choduraev[1]

[1] Ecology and Tourism of the Kyrgyz State University Named After I. Arabaev, 51, I. Razzakov St., Bishkek 720026, Kyrgyzstan
nalsur24@list.ru

[2] Institute of Geology Named After M. Adyshev of the National Academy of Sciences of the Kyrgyz Republic, 30, Erkindik St., Bishkek 720481, Kyrgyzstan

Abstract. In this article, attention focused on the analysis of the tightness of relationships between the runoff during the growing season and the main climatic factors of the formation of river flow in the annual and growing season. Long-term fluctuations in runoff during the growing season determined by cold precipitation in the catchment areas and the temperature regime of the summer months.2000 to 2019 the amount of precipitation in the upper reaches of the Naryn River between October to April increased significantly. The sum of positive air temperatures has increased most significantly over the past twenty years in the alpine zone and over the past forty years—in the lower reaches of the catchment. The number of days with positive temperatures is also increasing. For example, in the high mountain zone over the past 20 years it has increased from 109 to 122 days, and in the middle mountain zone of the river—from 220 to 236 days over the past 40 years. As a result, the air temperature above 0 °C shifted from mid-May–June to April–May at the Tien-Shan meteorological station, from mid-March to the first half of March at the Naryn meteorological station. Therefore, the runoff of the upper reaches of the Naryn River during the growing season, according to the data from the Naryn gauging station, Naryn city, has been increasing the average growing water discharge since 1992.

Keywords: Summer runoff · Vegetation period · Water consumption · Climatic factors · Hydrological regime · Water supply · Gauging station

1 Introduction

The Naryn River is the largest water artery in Kyrgyzstan. In the outlet section (hydropost Uchkurgan), the area of the basin is 58400 km2, the annual discharge is estimated at 432 m3/s [1–4]. Its runoff used for hydropower and water management purposes. In the future, it planned to build 24 hydroelectric power stations in the Naryn river basin. At

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the same time, their construction in the upper reaches of the Naryn River was planned for the coming years. This determines the relevance of studying the water regime of the Naryn River.

The hydrological regime of the upper reaches of the Naryn River was described according to the data of a hydrological station located in the city of Naryn; climatic characteristics were determined according to long-term data of the Tien Shan meteorological station (3614 m above sea level) and Naryn (2040 m above sea level).

2 Relevance, Scientific Significance of the Issue

The problem of water supply for the population and various sectors of the economy has become relevant for many regions of the world. The uneven distribution of river flow within regions is becoming a serious problem, especially in arid regions of the world. These regions include the Central Asian region.

Kyrgyzstan has changed water relations with neighboring Republics. According to previous agreements, the use of water from the Toktogul reservoir, compared to energy, was focused on irrigation purposes. Energy is currently at the forefront.

This is due to the fact that Kyrgyzstan uses only 2% of the total volume of water from the Nizhne-Naryn HPP for irrigation. In addition, Toktogul HPP cannot provide electricity in autumn and winter. Due to the fact that an average of 11 billion m3 of water per year from the Toktogul reservoir used to irrigate the territories of Uzbekistan, Tajikistan and Kazakhstan. Under such conditions, Kyrgyzstan faces difficulties in managing the water regime of the Toktogul HPP due to a decrease in electricity supply in the winter.

At the same time, population growth observed in Kyrgyzstan, new houses and enterprises are being built. The expansion of irrigated lands is becoming an urgent task, the solution of which is necessary to provide the growing population with agricultural products.

3 Formulation of the Problem

The paper sets the task to investigate the hydrological regime of the upper reaches of the Naryn River (Narynhydropost, Naryn city) since 1930. Therefore, it is necessary to modernize and develop the systems of water supply, energy and water resources management. In this regard, one of the most important scientific and practical issues is the hydrological analysis of the flow of the Naryn River and the forecast of fluctuations in water content in the Toktogul reservoir to optimize the cost-effective operation of the Toktogul HPP.

4 Theoretical Part

The distribution of runoff within a year determined by the time when water enters the river system from genetic sources—snow, glaciers and rains. In the conditions of Kyrgyzstan, regulated by the peculiarities of orography and relief—the distribution of watershed areas in altitudinal zones and exposures—relative to moisture-bearing air masses, synoptic conditions of the cold and warm periods of the year.

Many scientists have developed theoretical foundations and methods for studying the hydrological characteristics of the rivers of Kyrgyzstan, including the Naryn river basin. These include V.L. Schultz "Rivers of Central Asia", 1965, D.M. Mamatkanov "Modeling and prediction of fluctuations in river flow", 1973, M.N. Bolshakov "Water resources of the rivers of the Soviet Tien Shan and methods for their calculation", 1974, S.K. Alamanov "Study of the formation and long-term forecast of river flow in the north-west of Kyrgyzstan", 1977, A.G. Grinevich, E.K. Pospaeva "Characteristics of vegetation runoff in the basin of the river. Naryn and questions of its forecasting", 1975, I.V. Ratsek "Oscillations and evolution of glacial runoff in the basin of the river. Naryn", 1991.

5 Practical Significance, Suggestions and Results of Implementations

To assess the situation in the upper reaches of the Naryn River, hydrological and meteorological data from the archive of the Hydrometeorological Service of the Kyrgyz Republic used for the period 1930–2020. Were applied Statistical, geographical and hydrological methods.

According to the data of the gauging station in the city of Naryn for 1930–2020, it can be seen that the average water discharge for the growing season has increased since 1992 (Fig. 1). So, if the average vegetation flow in 1931–1991 was 144.7 m^3/s, later for the period from 1992 to 2020 it increased to 173.9 m^3/s, or by 120%.

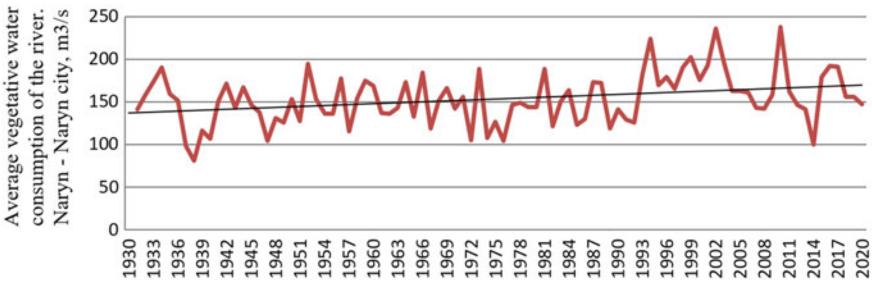

Fig. 1 Changes in water discharge on the river Naryn (hydropostNaryn from 1930 to 2020)

The study of the Naryn River's feeding sources during the growing season showed that in upper reaches the increasing of water inflow in April-June occurs mainly due to snow melting, and in July–September—due to ice and high-mountain snow melting [5–7]. Calculations based on data for 1992–2020 showed that the ratio of the water content of the Naryn River by months of the growing season distributed as follows: 26% of the flow fell on July, 23% on June and August, 13% on May, 10% on September and 5% in April, as seen in Fig. 2.

The results of analyze Fig. 3, show that the supply of the river with glacial water decreased compared to its supply with snow water (Fig. 3). Since 1992, the part of the July runoff in the vegetation season of the total runoff has decreased by 10%, (Fig. 4).

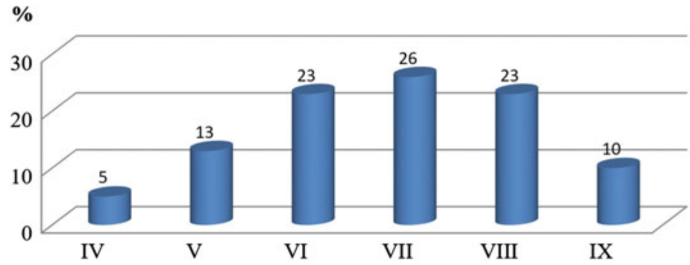

Fig. 2 Percentage of monthly runoff to vegetation runoff (Naryn gauging station)

According to V.A. Kuzmichenok and A.N. Dikikh [7–9], the relative decrease of glacial water part in the river associated with a decreasing of the glacier's area and the attraction of the lower boundary of the firn upwards. In August, the share of runoff did not change, while in September, on the contrary, it increased (about 1%). As shown on Fig. 4 the share of river feeding by melt waters (April-June), on the contrary, increases. Following this trend, the maximum water inflow gradually shifts from July to May–June.

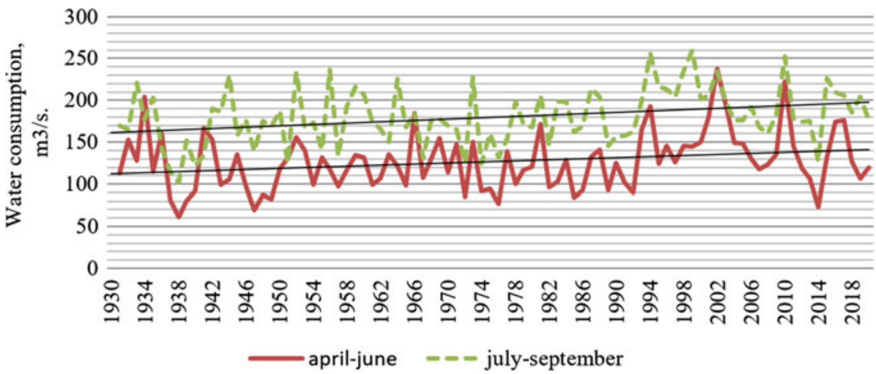

Fig. 3 The ratio of the river's supply of melted snow water (April–June) and melted glacial water (July–September)

The temperature regime of the summer months and precipitation falling on the river catchment during the cold season play a key role in the formation of long-term runoff fluctuations during the vegetation season. In other words, climatic factors determine the formation of runoff [10–13]. For example, over the past 20 years, compared with 1930–1999 [14, 15], the amount of precipitation in the cold seasons of the year has increased, (Fig. 5). So, in October–April in 1930-2019p Precipitation in the upper reaches of the Naryn River increased from 646.8 mm to 1168 mm at the Tien Shan meteorological station and from 977.5 to 1401.8 mm at the Naryn meteorological station. As a result, the flow of the Naryn River also increased [16], as shown in Fig. 1. A.N. Dikikh [7] noted a decrease in the water level in the upper reaches of the Naryn River due to a precipitation decrease during the cold periods of the year in 1930–1998.

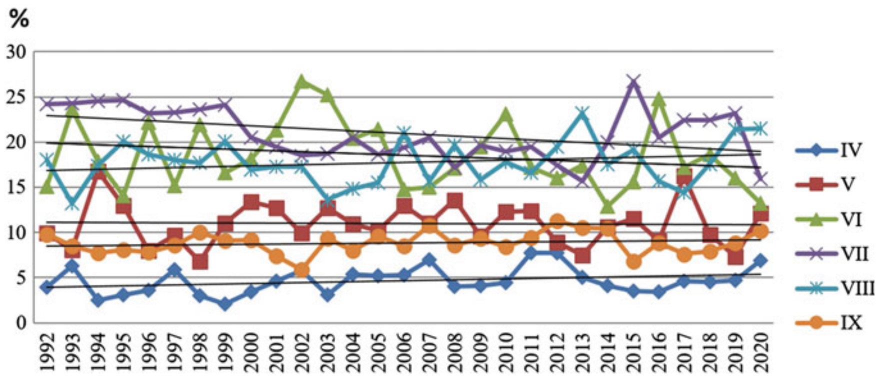

Fig. 4 Changes in the share of monthly runoff in the total runoff of the vegetation season

Analyzing the data of the Naryn and Tien Shan weather stations, we notice climatic conditions changes in the upper reaches of the Naryn River over the past 20–40 years [6].

The sum of positive air temperatures at the Tien Shan weather station increased from 95.4 to 168.7 °C, at the Naryn weather station from 827.4 to 947 °C (Fig. 6).

The number of days with positive temperatures also increased. For example, in the high mountain zone over the past 20 years it increased from 109 to 122 days, and in the middle mountain zone of the river—from 220 to 236 days over the past 40 years. As a result, the air temperature above 0 °C shifted from mid-May–June to April–May at the Tien-Shan weather station, from mid-March to the first half of March at the Naryn weatherl station [17, 18].

The analysis of the average annual water consumption at the Naryn hydropost and the correlations of the average monthly air temperatures at the Naryn and Tien Shan weather stations showed that the correlation between summer air temperatures and runoff at the Tien Shan weather station is very close (Fig. 7). According to O. Yu Kalashnikova. Studies [19, 20], the summer runoff of the upper reaches of the Naryn River during the vegetation season was 72% of the annual volume. In the summer months, the tendency of the air temperature raised. At the Tien Shan weather station, the air temperature in the summer months of 1930–2019 increased by 1.2 °C (Fig. 8). In the summer months, there is a tendency to increase the air temperature.

In addition to climatic parameters, the vegetation period of runoff is influenced by low water flow (October–March) Fig. 9. For example, Fig. 10 shows that the low water flow runoff has been increasing since 1992. The low water flow runoff was 29.9 m^3/s in 1931–1991 and increased by 37.7 m^3/s or 120% in the period from 1992 to 2017.

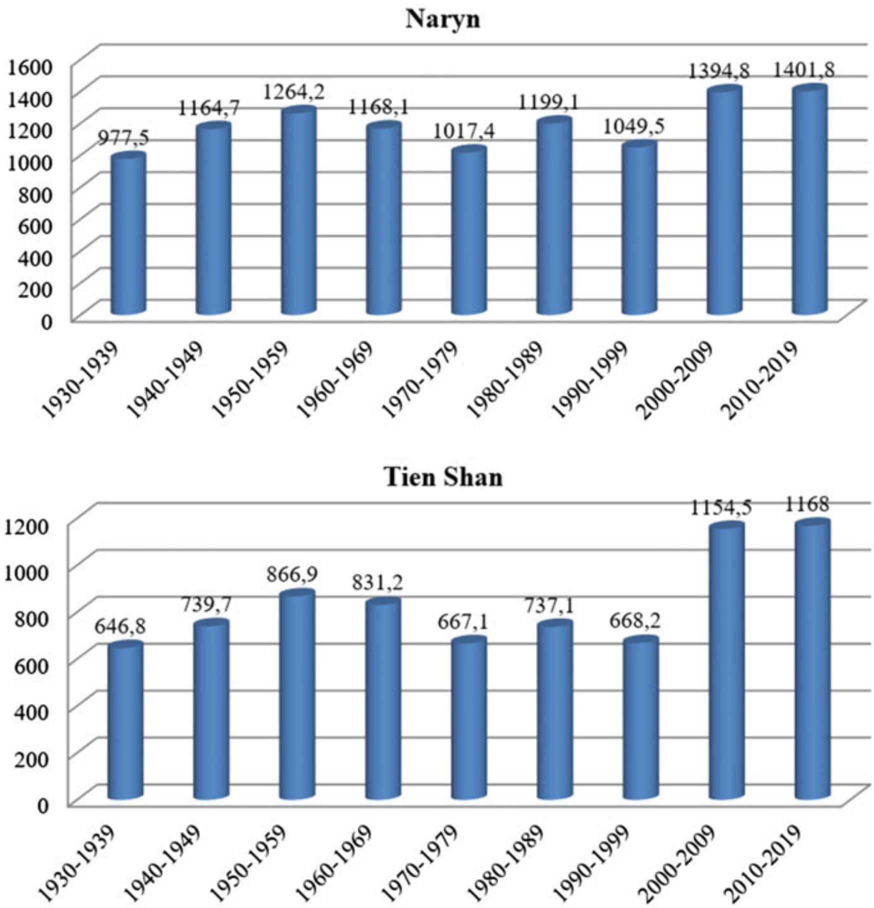

Fig. 5 Changes for precipitation (in mm) from October to April at Naryn and Tien Shan weather stations

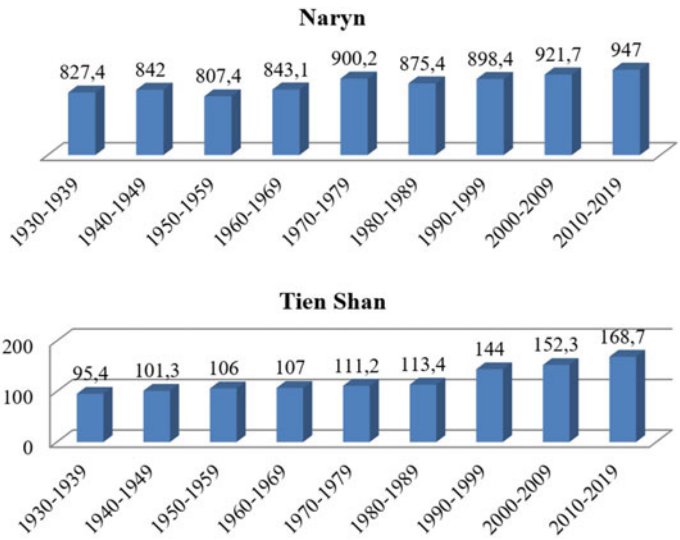

Fig. 6 Sum of average annual positive air temperatures at Naryn and Tien Shan weather stations

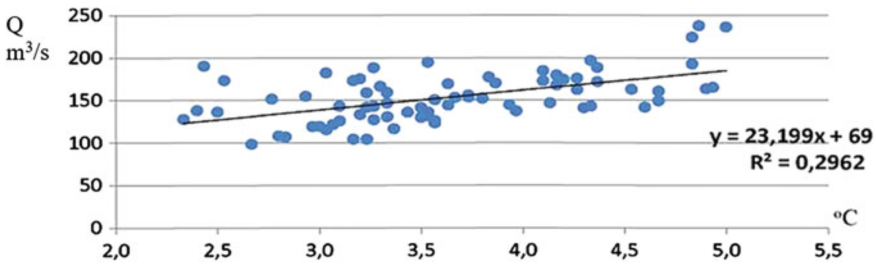

Fig. 7 Dependence of the average vegetation water consumption at the Naryn hydropost on the average air temperature in June-August at the Tien Shan weather station

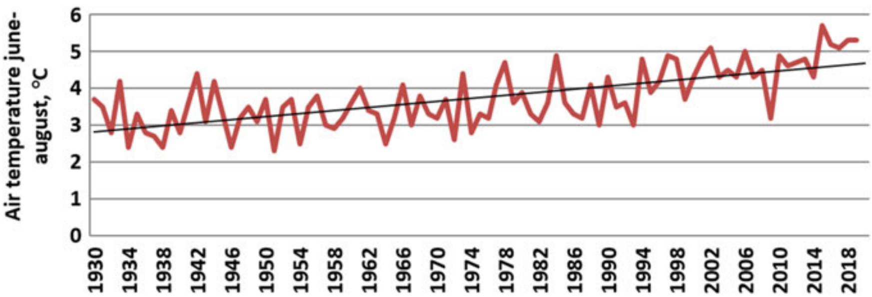

Fig. 8 Changes in the average air temperature in June–August according to the data of the Tien Shan weather station

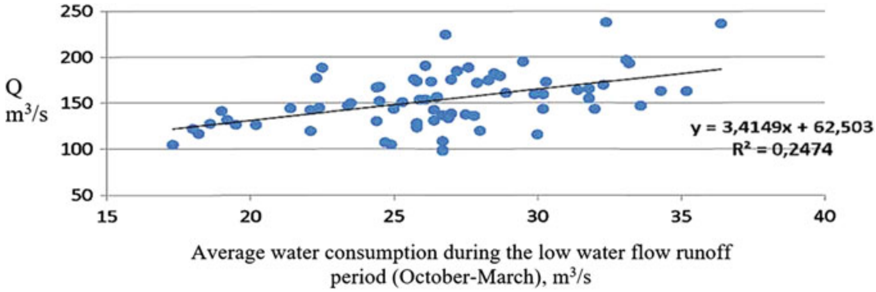

Fig. 9 Dependence of the average vegetation water consumption at the Naryn hydropost on the average water consumption during the low water flow runoff period

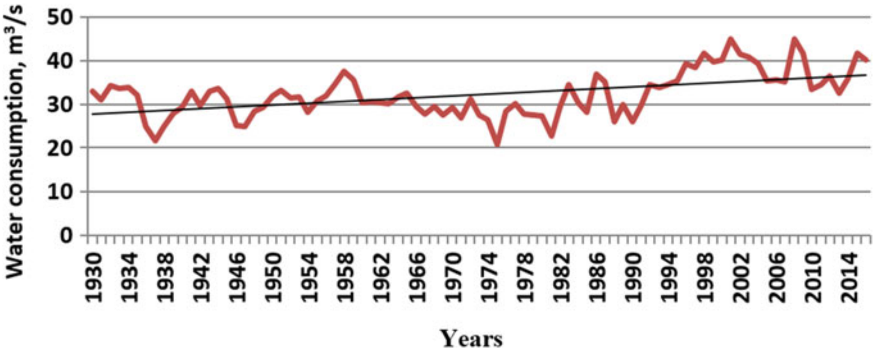

Fig. 10 Change in water consumption of the Naryn hydropost during the low water flow runoff period (m^3/s)

6 Conclusion

Since 1992, according to the data of the Narynhydro postwater discharges increased in the upper reaches of the Naryn River. The average vegetation period runoff was 144.7 m^3/s in 1931–1991, and over the period from 1992 to 2017 it increased by 173.9 m^3/s or 120%. In 1992–2017, the share of runoff in July (powered by melting glaciers) decreased by 10% at the Narynhydro post. In 1930–2019, in the upper reaches of the Naryn River, the amount of precipitation in October–April increased from 646.8 to 1168 mm at the Tien Shan weather station and from 977.5 to 1401.8 mm at the Naryn weather station. The sum of positive air temperatures at the Tien Shan weather station increased from 95.4 to 168.7 °C, and at the Narynweather station from 827.4 to 947 °C.

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