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Modeling the Runoff of Mountain Rivers in the Ferghana Valley based on the Multivariate Regression Equation

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Abstract: A mathematical model of the formation of the runoff of a mountain river is constructed on the basis of the water balance equation. The water balance equation is converted into a multivariate regression equation. The regression coefficients are found and allow calculating the runoff of a mountain river based on climatic characteristics.

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1. Introduction

Many studies of the impact of climate change on water resources and mountain river flow are based on the analysis of the air temperature regime in the river basin which determines the regime of glacier and snow melting. Studies of the dynamics of the precipitation regime determine the hydrological regime of the river runoff. The regime of precipitation and the regime of melting of glaciers and snow cover determine the flow of the river however for practical purposes these factors are difficult to use when calculating the balance of water resources [3,4] . For practical application, it is proposed to use the trends of the direct river runoff over the observation period.

The UNESCO report [6] “Water and Climate Change»-2020”, it is noted that climate change manifests itself, in particular, in changes in the hydrological regime of rivers, the regime of glaciation and other water bodies [1,2,4].

As an example, consider the formation of the flow of the Sokh River (Fergana Valley). According to the type of feeding the Sokh River belongs to the glacier-snow which means a significant contribution of the glacial component to the total volume of annual and vegetation runoff. According to numerous studies of the mountainous territory of Central Asia it is noted that over the period 1980-2010 the area of glaciation has significantly decreased which in turn can lead to a reduction in the volume of glacial runoff.

Warming in the highlands of the Pamirs, Tien-Shan, Gissar-Alay and other mountain systems is in line with regional and global trends. Glacial reserves concentrated in the mountainous regions of Central Asia are the most important source and long-term reserve of clean fresh water.

2. Material and Methods

The study area is located between 40°18 and 39°40 N latitudes, and between 71° 7'2 and 71°29 E longitudes, in the elevational belt of 440-4000 m in Fergana Valley.

If the current rates of glaciation degradation continue many small glaciers will completely disappear in the next 30-40 years. The degradation of glaciation can most strongly affect the regime of the Sokh River.

Let us consider the influence of hydrometeorological parameters observed at the Sarykanda meteorological station on the flow of the Sokh River in the Sarykanda hydrological station during the growing season (April-September) using the multiple regression equation:

$$Qveg = \alpha\ Xwinters + \beta\ Xveg + \gamma\ Tveg, \qquad (1)$$

where Qveg is the average water consumption for the vegetation season, Xwinters is the amount of precipitation for the winter period (October-March), Xveg is the total precipitation for the vegetation season, Tveg is the sum of air temperatures for the growing season, α, β, γ are the coefficients of the standardized (normalized) multiple regression equation.

As a result of the calculations, a standardized (normalized) form of the regression equation was obtained:

Qveg =0.339 Xwinters + 0.542 Xveg + 0.597 Tveg, (2)

Determination coefficient R2 =0.4927, multiple correlation coefficient K=0.702. The contribution of the components Xwinters = 22.9% , Xveg = 36.7% , Tveg = 40.4%, without taking into account the contribution of underground inflow, which is practically constant throughout the year.

Groundwater is the main source of saturation of the Sokh River before the start of the flood period and after the end of the phase of this water regime [1, 2].

When the river is saturated during the flood period then the share of groundwater decreases due to the increase in the share of water formed as a result of the melting of glaciers and snow cover.

The increase in the polynomial trend of the vegetation runoff of the Sokh River since 1978 can be interpreted as an increase in air temperature in the high-mountain zone and the ongoing melting of glaciers in the summer. Also, the trend increase is influenced by a change in the precipitation regime, especially in the form of heavy rains in the spring-summer period.

Table 1 shows the standardized regression equations for calculating the flow of the Sokh River in individual months of the growing season with the corresponding determination coefficients. Notations for normalized values are used: average water consumption per month - ty ; average water consumption for the previous month - x1 ; the amount of precipitation for the previous and calculated month - x2 ; sums of air temperature for the previous and settlement month - x3 .

However, when the calculation period is shortened it leads to an increase in the correlation coefficient. To obtain the calculation equation, the period from 1998 to 2018 was taken.

Equation obtained:

$$y=0.0039*x4 - 0.1851*x3 + 2.9076*x2 – -15.872*x + 104.9, \quad (3)$$

for this multiple regression coefficient R^2 = 0.3181, multiple linear correlation coefficient K=0.56.

Figure 1 shows the combined runoff hydrograph for the growing season. There is a noticeable improvement in the tightness of the connection which is apparently associated with climate changes that affect the dynamics of meteorological changes and their impact on runoff formation. In addition, we can note the ongoing reduction of high-mountain glaciation.

The hydrological regime of a river of glacier-snow type of nutrition is significantly influenced by the air temperature in the river basin. The beginning of the increase in the runoff hydrograph (the beginning of the spring flood) occurs at the end of March- the beginning of June and the spring flood continues in September, with the transition to a low-water regime in October-December.

The hydrological regime of the Sokh River during the growing season is determined more by the air temperature regime (40.4%) and consequently by the melting of glaciers in the summer and precipitation during the vegetation season (36.7%).

3. Results

For this reason, it is difficult to build predictive dependencies based on the amount of winter snow reserves and the temperature regime for the previous period.

The calculated regression equations for the runoff of the Sokh River on air temperature for certain periods show that the runoff during the growing season depends on the air temperature for the same period to a greater extent than for the periods of flood rise and fall.

The results obtained will make it possible to develop new recommendations and update the existing standards governing the operation of the water management complex and the design of water management facilities bringing them in line with modern conditions and taking into account ongoing and expected climate changes in the future.

Table 1. Standardized multiple regression equations for calculating the flow of the Sokh River in individual months of the growing season

Month	Standardized Form of Multiple Regression Equations	Coefficient Determinations
April	ty = 0.544x1 + 0.351x2 + 0.227x3	R^2= 0.6652 = 0.4415
May	ty = 0.392x1 + 0.225x2 + 0.485x3	R^2= 0.6702 = 0.4491
June	ty = 0.291x1 + 0.487x2 + 0.463x3	R^2= 0.6472 = 0.4188
July	ty = 0.421x1 + 0.214x2 + 0.222x3	R^2= 0.5482 = 0.3002
August	ty = 0.277x1 + 0.233x2 + 0.474x3	R^2= 0.5722 = 0.3272
September	ty = 0.385x1 + 0.214x2 + 0.237x3	R^2= 0.5712 = 0.3265

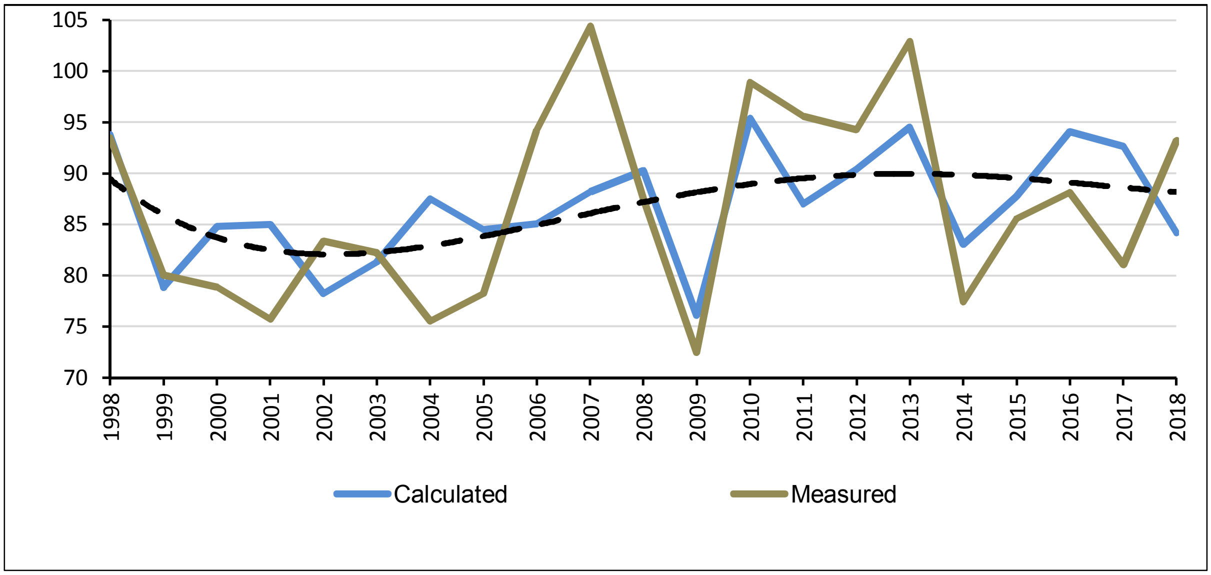

Figure 1. Combined hydrographs of the Sokh river runoff calculated, observed and polynomial trend line.

4. Discussions

As a result of climate change and the observed change in the precipitation regime and air temperature, which affect the regime of formation of the flow of mountain rivers, an inevitable change in the flow regime occurs. In the overall balance of the water cycle, there is also a change in runoff.

The change in the runoff regime of mountain rivers itself can be considered as a climatic factor that can be directly analyzed and be of direct interest for analysis. The climate affects not only air temperature, but also indirectly other causes and parameters that change the flow of rivers.

Due to the fact that for users of water resources the most important factor is the direct change in water resources, in this case, to predict the amount of water resources, it is directly necessary to use trends in the amount of water in the river runoff. The use of multivariate regression methods to identify the dynamic characteristics of runoff makes it possible to directly study the dynamics in the process and identify additional factors that determine the formation of water resources.

Of particular importance is the territory under study, landscape characteristics, relief parameters, soil cover and groundwater.

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