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EVALUATION OF RUNOFF SENSITIVITY WITH RELATION TO CLIMATE VARIABILITY FROM EMPIRICAL-STATISTICAL MODEL OF THE RIVER MTKVARI

It is known that general water cycle system “atmosphere-earth surface” contains reincarnation of water vapor in the following way: ”water provision in atmosphere - cloudiness (nebulosity) – precipitation – evaporation - runoff”. The nebulosity, precipitation and vapor mainly depend on temperature and humidity of atmosphere regime. So, variability of those may stimulate significant variance of water cycle components. Therefore, the study of climate variability influence on water balance and runoff is a main problem for research of regional climate variance.

The aim of present work is to estimate annual runoff reaction to the variability of some climate parameters - total precipitation, relative humidity. For the creation of empirical-statistical used long time series of climatic data of river Mtkvari model have been.

For the establishment of dependence of mean annual runoff on climatic predictors correlation matrix of the river Mtkvari for Tbilisi section has been calculated. These predictors are: runoff R (m^3/s), total precipitation P (mm), air temperature T_1(^{0}C), water vapor pressure e (mb), relative humidity f(%), sunshine duration *S(hr)*, wind velocity V (m/s), soil temperature T_0 (^{0}C).

For calculation we have analyzed the observational data of the Tbilisi meteorological and hydrological station – random numbers of analogue data series are N=55 (1936-1990). The correlation matrix is presented in Table 1.

Table 1. Matrix of correlation (N=55; 1936 – 1990)

Predictors	R	P	T_1	e	f	S	V
Average	204.0	525.7	13.06	10.55	65.99	2038.0	1.88
Standard deviation	43.88	115.2	0.65	0.41	1.99	149.5	\0.66
R	1	0.306	-0.175	-0.115	0.256	-0.277	0.213
P		1	-0.365	0.168	0.535	-0.323	\0.123
T_1			1	0.436	-0.324	0.180	-0.035
e				1	0.427	-0.183	\-0.337
f					1	-0.326	\0.109
S						1	\0.266
V							1

Analogical calculation has been done for checking up stability of correlation coefficients – random numbers of analogous data series are N=37 (1954 – 1990). Results of calculation are presented in Table 2.

Table 2. Matrix of correlation (N=37; (1954 – 1990)

Predictors	R	P	T_1	e	f	S	V	T_0
average	197.5	513.0	13.09	10.67	65.98	2035.0	1.59	15.1
Standard deviation	41.74	119.3	0.73	0.38	2.07	148.8	0.57	0.1
R	1	0.228	-0.347	-0.091	0.323	-0.141	-0.018	-0.380
P		1	-0.409	0.265	0.517	-0.371	-0.074	-0.446
T_1			1	0.538	-0.346	0.250	-0.038	0.894
e				1	0.383	-0.103	-0.186	0.402
f					1	-0.279	0.157	-0.325
S						1	0.501	0.214
V							1	-0.075
T_0								1

From the analysis of both matrices of correlation predictors have been selected by their stability. Total precipitation and relative humidity have been selected as predictors. Correlation coefficient values in this case are equal to:

r_{12} = 0.306 (0.228), r_{15} = 0.323 (0.256).

By an original method elaborated in [1], the following empirical and statistical model has been obtained:

$$R = c_1+c_2f+c_3f^2+(d_1+d_2f+d_3f^2)P \quad (1)$$

where P is total precipitation (mm), f - relative humidity (%) and R - runoff (m^3/s).
The values of coefficients are:

c_1 = 80012.90; c_2 = -2434.62; c_3 = 18.54;
d_1 = -150.60; d_2 = 4.58; d_3 = -0.035.

By putting the parameters of the correlative matrix in the equation (1) (Table 1, f = 66%, P = 525.7 mm), we obtain runoff equation R = 206 m^3/s, that coincides with its table value (R = 204 m^3/s) with 1% precision.
In our case the variability of runoff is expressed by the following equation [2]:

$$dR = (\partial R/\partial P)dP + (\partial R/\partial f)df , \quad (2)$$

where sensibility to precipitation variation is equal to:

$$(\partial R/\partial P) = d_1+d_2f+d_3f^2, \quad (3)$$

and sensibility to relative humidity is equal to:

$$(\partial R/\partial f) = c_2 + 2c_3f + (d_2+2d_3f)P. \quad (4)$$

Inserting (3) and (4) in (2), for runoff variability we obtain:

$$dR = (d_1+d_2f+d_3f^2)dP + (c_2 + 2c_3f + (d_2+2d_3f)P)df . \quad (5)$$

If we consider the input data of matrix correlation R = 204 m^3/s, P = 525.7 mm,
f = 66%, finally we have:

$$dR = 0.25dP + 5.41df . \quad (6)$$

According to [3], the secular variation of relative humidity for Tbilisi is equal to 1 - 2 % (df =1–2 %), that is the maximum value for Eastern Georgia.
From the equation (6) for the variance of runoff, we have the following estimations:

Scenario I: dP = 105.14 mm (20%); df = 2% (3%).
dR = 0.25x105.14+5.41x2=37.105 m^3/s (18%).

Scenario II: dP = 52.57 mm (10%); df = 2% (3%).
dR = 0.25x52.57+5.41x2=23.963 m^3/s (12%).

Scenario III: dP = 26.285 mm (5%); df = 2% (3%).
dR = 0.25x26.285+5.41x2=17.391 m^3/s (8.5%).

Scenario IV: dP =0 mm (0%); df = 2% (3%).
dR = 10.82 m^3/s (5.3%).

Scenario V: dP = -26.285 mm (-5%); df = 2% (3%).
dR = -0.25x26.285+5.41x2=4.249 m^3/s (2%).

Scenario VI: dP = -52.57 mm (-10%); df = 2% (3%).
dR = -0.25x52.57+5.41x2=-2.323 m^3/s (-1%).

Scenario VII: dP = -105.14 mm (-20%); df = 2% (3%).

$dR = -0.25x105.14+5.41x2=-15.465\ m^3/s$ (-7.6%).

Scenario VIII: $dP = -105.14$ mm (-20%); $df = 1\%$ (1.5%).
$dR = -0.25x105.14+5.41x1=23.963\ m^3/s$ (-10%).

Scenario IX: $dP = -105.14$ mm (-20%); $df = -2\%$ (-3%).
$dR = -0.25x105.14-5.41x2=-37.105\ m^3/s$ (-18%).

Scenario X: $dP = -105.14$ mm (-20%); $df = 2\%$ (3%).
$dR = -0.25x105.14+5.41x2=-15.465\ m^3/s$ (-7.6%).

Scenario XI: $dP = -52.57$ mm (-10%); $df = 2\%$ (3%).
$dR = -0.25x52.57+5.41x2=-2.323\ m^3/s$ (-1%).

So, in case of the use an empirical-statistical model, the sensitivity in the variance of the both predictors is positive. When P and f are increasing, the runoff is increasing as well and vice-versa:

$$(\partial R/\partial f) = 0.25\ , \qquad (\partial R/\partial P) = 5.41\ . \qquad (7)$$

Hence, the sensitivity of the runoff to relative humidity variation is approximately 22 times as much than the sensitivity of precipitation variation

$$(\partial R/\partial f) / (\partial R/\partial P) = 22\ .$$

According to the most probable climatic scenario, if $df = 2\%$ [3], we will get a linear relationship between the runoff and precipitation variations:

$$dR = 0.25\ dP + 10.82\ . \qquad (8)$$

Proceeding from the above-mentioned data, we can determine the relation between the runoff sensitivity and variation of other meteorological parameters (air temperature, relative humidity, etc.). Also, it is possible to evaluate the runoff reaction to the variation of these parametres.

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Assessment of the sensitivity of River Kura runoff towards the climate variability on the basis of empirical-statistical model./N.N.Begalishvili, K.A.Tavartkiladze, N.A.Begalishvili/. Transactions of the Institute of Hydrometeorology. 2001.-V.106.-p.154-158.- Eng.:Summ.Georg., Eng., Russ.

Statistical model is constructed for the River Kura runoff (hydrological section Tbilisi) depending on precipitation, air temperature and elements of atmospheric moisture content (water vapor density and relative humidity) based upon the Tbilisi weather station data for the period of 1936-1990. Applying this model the sensitivity of runoff to climate variability is assessed and possible scenarios of runoff secular variations are determined for the given fluctuations of climatic elements.Tab.2,Ref.3.

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Оценка на основе эмпирико-статистической модели чувствительности стока р.Куры относительно климатических изменений./Н.Н.Бегалишвили, К.А.Таварткиладзе, Н.А.Бегалишвили/.Сб. Трудов Института гидрометеорологии АН Грузии. – 2001. – т.106. – с.154-158. – Анг.; рез. Груз.,Анг.,Русск.

Построена статистическая модель стока р.Куры – гидроствора Тбилиси в зависимости от осадков, температуры воздуха и элементов влагосодержания атмосферы (упругости водяного пара и относительной влажности) по данным метеостанции Тбилиси (за период 1936-1990 гг.). На основе представленной модели оценена чувствительность стока относительно климатических изменений. Определены возможные сценарии вековых изменений стока при заданных вариациях климатических характеристик.Таб.2,лит.3.