Creation of adaptation mechanisms: the key to more cost-effective and environment-friendly water management

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In the Central Asia region, with its inherent climatic conditions, the choice of place and geographical location for building reservoirs is a problem. Estimation (Shirokov & Lopukh, 1985) of the degree of influence of reservoirs in arid zones on the surrounding environment is possible by the use of coefficient $K_{sur.env}$:

$$K_{sur.env} = \sum S_i / S_{oi} \cdot 100\% \quad (1)$$

where $K_{sur.env}$ is the coefficient of reservoir influences on environment; S_i, area of the territory under the influence of the reservoir (km^2); S_{oi}, basin area (km^2).

The degree of influence of reservoirs on adjoining land decreases as they decrease in size and volume, and *vice versa*. This feature should be considered when creating new reservoirs in Tajikistan and also when building developments for lake-side recreation, creating zones with more recreation services (Normatov & Petrov, 2005).

For an estimation of the role of the reservoirs as a local climate formation factor it is possible to use the ration $\Delta P/\sigma_{sp.dif.}$, where ΔP is the influence indicator, and $\sigma_{sp.dif.}$ is the mean square deviation of differences of the property between two stations located at a distance 10–20 km. At $\Delta P/\sigma_{sp.dif.} \geq 1$, there is a definite influence of the reservoir on the meteorological conditions. These criteria are being used to estimate the role of reservoirs as factors influencing formation of local meteorological conditions and the agroclimatic parameters of the lake-side region and also the thermal properties of the river downstream of reservoirs.

Before the filling of Nurek Reservoir, there was practically no difference in water temperature of the Vakhsh River water at Nurek HPS Dams (kishlak Tutkaul) and temperature at a distance of ~17 km below the dam (kishlak Sariguzar). With filling of the Nurek Reservoir (in 1972) a decrease in water temperatures was observed in spring (February–May) and a rise in summer–autumn–winter (July–January) in comparison with natural conditions. Since 1972, the influence of the Nurek Reservoir on the thermal regime of the Vakhsh River water has been be recorded very precisely on the 17 km of the river downstream of the Nurek HPS Dam to the hydrological station at Sariguzar. The greatest difference in average monthly temperature of water before and after construction of the reservoir at Sariguzar (4.2°C) is observed in November–December. Further downstream, this difference decreases to 1.2°C. The influence of small channel reservoirs on change of water temperature with length of the river are traced for a significant distance downstream (Table 1).

Table 1 Average monthly temperatures of Vakhsh River water before and after building of the Nurek.

River-Hydropost		I	II	III	IV	V	VI	VII	VIII	I X	X	XI	XII
Vakhsh–Tutkaul	1946–1967	2.6	4.3	7.6	11.0	12.8	14.3	15.0	14.9	13.6	11.2	6.7	3.4
Vakhsh–Sariguzar	1967–1971	2.0	4.0	8.1	11.5	13.2	14.4	15.0	14.9	13.5	11.2	7.6	4.8
Vakhsh–Sariguzar	1972–1980	5.4	3.9	5.5	10.0	13.0	14.9	15.9	16.0	15.3	14.0	11.8	9.0
Difference		–3.4	0.1	2.6	1.5	0.2	–0.5	–0.9	–1.1	–1.8	–2.8	–4.2	–4.2

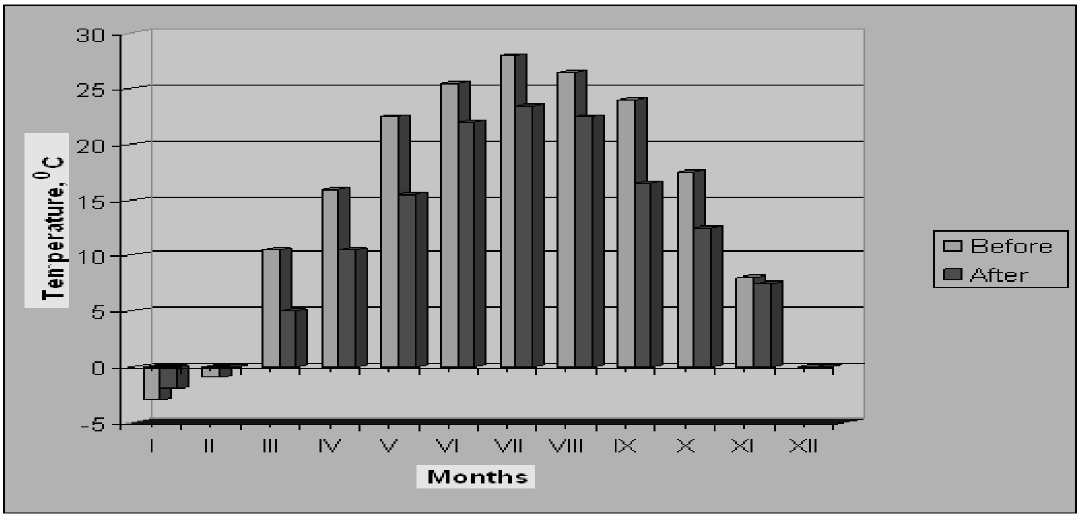

Fig. 1 Average monthly temperature before and after building of the Nurek Reservoir.

The hot water temperature influence is traced over a length of river 1.74 times greater (209 km), than that of the inputs of cooled waters (120 km). Hence, the change of the annual distribution of average monthly values of water temperature below large reservoirs, for a given time interval, is not connected to the change of annual means of air temperature, but is influenced by the reservoirs of the cascade. However, according to data of Nurek station, monthly average temperature after construction of Nurek HPS has gone down (Fig. 1).

To establish the influences of climate change on possible changes of agroclimatic resources, we made an analysis of climatic parameters of three districts with developed agricultural branches (Dangara, Fayzabad and Yavan) adjoining the Nurek Reservoir. For this purpose, data of hydrometeorological stations (HMS) located in these areas have been used, including air temperature and relative humidity, and precipitation for 1968–1988. The evaporation and humidity coefficient were defined by calculation (Table 2).

Table 2 Summary of meteorological indexes in each district.

Hydropost	Index	Years 1968–1972	1995–2000
Dangara	T (°C)	15.3	16.4
	H (%)	57.0	56.9
	F (mm)	570.5	598.5
	I (mm)	1196.7	1438.0
Fayzabad	T (°C)	13.2	15.4
	H (%)	61.6	55.2
	F (mm)	709.0	675.4
	I (mm)	1013.0	1258.8
Yavan	T (°C)	17.2	16.9
	H (%)	47.2	50.4
	F (mm)	677.4	677.3
	I (mm)	1630.8	1567.5

T: temperature, H: humidity, F: precipitation, I: evaporation.

The data presented in Table 2 demonstrate that for 20 years (1968–2000) the average annual temperature has risen by 1.0–1.5°C, which has led to decrease of the relative humidity by 3–6% and to increased evaporation of 10–26% per year, and 12–30% in the period May–September. However, in Yavan district the dynamics of the changes of the listed parameters has the opposite tendency: the air temperature and evaporation decreases by 0.5°C and 7.2%, respectively, and relative humidity and factor of humidity rise by 7.2% and 10% accordingly.

Reduction of the evaporation in the growing season in Yavan district reaches 12.2%. In view of climatic changes it is necessary to bring corresponding corrective amendments in the planning of water use in agriculture.

In the development of an irrigation regime, it is usual to consider the meteorological parameters for all periods available, but this introduces errors. In the old irrigated and prospective irrigation files, due to ignoring the process of global climate warming, the irrigation regimes do not consider the growing needs for water. On the contrary, for the Yavan valley, the files recommend regimes of irrigation which are connected with over-expenditure of water resources. For example, the last specifications for irrigation regimes for the Yavan valley used an annual average mean humidity coefficient of 0.35, i.e. as for an area categorized as droughty. But data presented in Table 2 show that, for the last 20 years, evaporation in the valley has decreased by almost 300 mm (17%), the quantity of precipitation has risen by 70 mm (11%), and the humidity coefficient is now 0.45. Hence, the present irrigating norms for cultivation of middle-fibrous cotton and lucerne in Yavan valley, of 1100 m^3/ha and 3000 m^3/ha, respectively, are over-estimated. Calculations show that unproductive losses of water in two valleys are more than 60×10^6 m^3.

The analysis of the results of measurements of sediment load in irrigation water by filtration shows that before building of the Nurek Reservoir, each m^3 of Vakhsh River water contained up to 10 kg sediments, and annually more than 100 t of sediments rich with minerals were delivered in inflows to the agricultural fields. According to the Hydrometeorological Agency of the Republic of Tajikistan, since 1972 (the beginning of filling of Nurek Reservoir), mean annual sediment loads of the Vakhsh River at the kishlak Sariguzar station, 17 km below the Nurek HPS, decreased from 1000 g/s to 82 g/s in 1980. The Nurek Reservoir traps most of the sediment load of the Vakhsh River.

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