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ASSESSMENT OF CLIMATE CHANGE IMPACT ON HYDROLOGICAL REGIME OF APARAN RESERVOIR

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This study examines hydrological regime of Aparan reservoir and its vulnerability caused by climate change. Statistical models for forecasting of maximum fullness level and water inflow were developed in scope of this study. The developed models and the results derived from Community Climate System Model 4 (CCSM4) model are used for assessment of climate change impact on the Aparan reservoir hydrological regime. The results show high vulnerability to climate change. In particular, the reservoir's maximum fullness water level is expected to decrease in future due to significant temperature increase, and the decrease can reach up to 11m by 2100 under RCP8.5 scenario. By contrast there are high variablity and lower consistency in the results of vulnerability of water inflow and surface runoff depth attributed to the high uncertainties in precipitation projections.
Keywords: Aparan reservoir, maximum fullness level, surface runoff depth, climate change, precipitation, river inflow, vulnerability.

Introduction

It is of great importance to estimate the vulnerability of water resources, maximum fullness of reservoirs, as well as water inflow from rivers in Armenia under the global climate change conditions. The latter provides an opportunity to develop a rational usage and planning of water resources during the year, contributing to a number of water-related issues and risks. In order to analyse a hydrological regime, it is necessary to study meteorological conditions, since the role of meteorological factors in the formation of hydrological regime is significant.

Aparan reservoir is one of the major strategically significant water objects in Armenia. Aparan reservoir was built in the middle flows of Kasakh river, at an altitude of 1800 metre (m) (Fig.1a) b)). In the case of normal headwater level (NHL) - 1835.0m, the volume is 91.0 million m^3, and the water surface area of the reservoir is 7.3km^2. Dead storage capacity level is 1810m (volume - 6.48million m^3). The watershed area of reservoir is 656km^2, while weighted average height of the basin is 2280 metre above mean sea level. The reservoir's watershed area is composed of relatively young volcanic rocks, and it is characterized by a mountainous relief and deep valleys (Гидрометеорологический режим озер и водохранилищ СССР, 1985).

a) b)

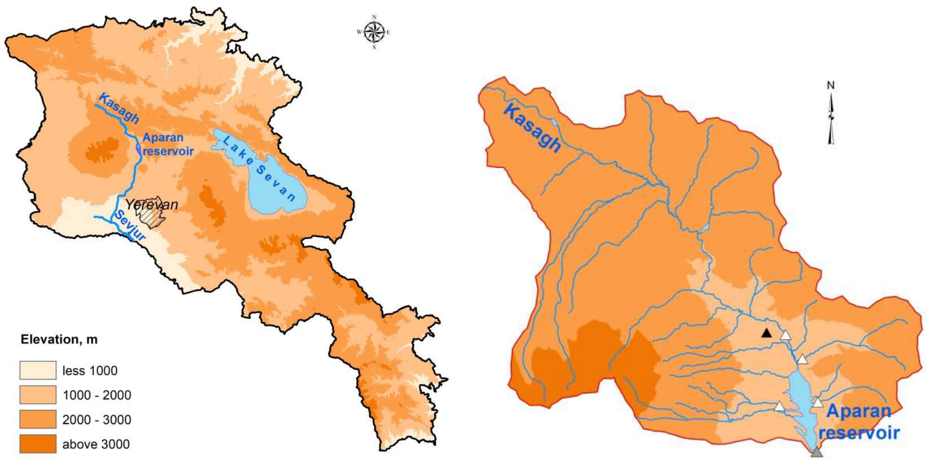


Fig.1. Topography maps of Armenia a) and catchment area of Aparan reservoir b).
Black triangle - Aparan meteorological station, white triangle - hydrological stations, grey triangle - Araran reservoir-Hartavan hydrological station.

The basin's climate is moderate, with short cool summers and relatively cold winters. In summary, the main climatic elements influencing the characteristic of reservoir's hydrological regime are insufficient moisture, sharp seasonal fluctuations of air temperature and precipitation, low wind speed and the lack of forest cover in the basin. According to the observational data of Aparan meteorological station (1890m) over 1961-90 the average annual temperature is 4.7^{0}C, while that for the warmest (July) and coldest (January) months are 16.9 and -8.8^{0}C, respectively (Կլիմայական տեղեկագիր I մաս, 2011). The amount of annual precipitation is 723mm. Precipitation are distributed inhomogeneously during the year, the maximum is observed in the May-June period. Snow cover forms every year, and it is retained from the beginning of December to the beginning of April. Ten-day average snow cover height is 48cm in the first decade of March (Կլիմայական տեղեկագիր II մաս, 2011).

The recent studies demonstrated that Armenia is affected by extreme precipitation events, heat waves, droughts, and significant temperature increase has been observed due to climate change, particularly, during the summer season (Gevorgyan et al. 2016). However, a little work has been done on studying climate change impact on water resources in Armenia, focusing on assessment of vulnerability of hydrological regime.

Data and Method

This study uses hydrometeorological observational network of Aparan catchment area (fig.1.b)). The water inflow and maximum fullness level forcasting for Aparan reservoir is based on the statistical regression method (Георгиевский, Шаночкин, 2007).

First, long-term observational data on daily average water level and maximum fullness level obtained from Hartavan hydrological station (Fig. 1.b) and air temperature and precipitation obtained from Aparan meteorological station were used to develop statistical forecasting method for Aparan reservoir maximum fullness level (H_{max}) during spring floods based on multifactorial correlation analysis (equation (1)):

$$H_{max} = 1813.21 + 0.031\sum X_{AparanIX-III} - 0.24T_{AparanII} -$$

$$0.34T_{AparanIII} - 0.47\Delta T_{AparanIV} + +2.72kX_{AparanIV} \quad (1)$$

where $\sum X$ – total precipitation amount for the station and months indicated in the index, T - mean monthly air temperature for the station and months indicated in the index, ΔT - air temperature anomaly relative to the norm of April, k - module coefficient of precipitation for April (i.e. the relative value of precipitations with respect to climatological norm). It should be noted that period of 1968-2004 was considered for development of the equation (1).

Aparan reservoir water inflow was defined as a sum of observed river inflow and estimated lateral flow components for the entire catchment area (Ամենամյա տվյալներ, 1968-2017). As predictors, observational data on air temperature and precipitation obtained from Aparan meteorological station and from high mountain Aragats (3229m) and Amberd (2071m) meteorological stations were used. Although Aragats and Amberd meteorological stations are located outside of the Aparan reservoir catchment area, those successfully represent climatic conditions of elevated parts of the basin. The prognostic equation for prediction of water inflow (W) to the reservoir during spring floods was obtained and presented in equation (2).

$$W_{IV-VI\ Aparan} =$$

$$-82.02 + 0.06\sum X_{Aparan\ XI-III} + 0.032\sum X_{Aragac\ VIII-III} +$$

$$0.18\sum X_{Amberd\ X-III} - -3.77T_{Aragac\ III} \quad (2)$$

The variables used in equation (2) are similar as in equation (1). Again, the period of 1968-2004 was consideredfor development of the equation (2).

The performance of the developed statistical relationships presented in equations (1) - (2) were estimated (Наставление по службе прогнозов, 1962, Wilks, 2006). First, permissible error for forecasting was estimated: $\sigma_{permissible} = \pm 0.674\sigma$, where σ -standart deviation. Then, the root-mean square error (RMSE) was evaluated following the equation $S = \sqrt{\frac{\sum_1^n (y-\acute{y})^2}{n}}$, where, S - RMSE, y- observed, and$\acute{y}$- forecasted values, n - the number of values in the series.

The assessment of future climate change impact on hydrological regime of Aparan reservoir has been performed using climate change projections of the Community Climate System Model 4 (CCSM4) developed by National Canter for Atmospheric Research (NCAR). The CCSM4 model has a 1.25°×0.9° spatial resolution, and it is considered as relatively high-resolution model among the global climate change models. The CCSM4 model uses updated physical parameterizations (cumulus convection scheme, a high-accuracy radiation scheme), as well as, new land models and aerosol effects on clouds (Gent et al., 2011). The CCSM4 was validated and used by Gevorgyan et al. (2016) for assessment of temperature change projections in Armenia over 21st century. Other recent studies demonstrated that the CCSM4 model was among the successful models from the list of models included in phase 5 of the Coupled Model Intercomparison Project (CMIP5) (Meleshko and Govorkova, 2013). The two high climate change scenarios used in this study for future precipitation and temperature change assessment are RCP8.5 (A2) and RCP6.0 (B2) scenarios. In order to downscale the CCSM4 model output data to the area of Aparan reservoir (Figure 1.b)) the simple bilinear interpolation was applied.

Hydrological regime of Aparan reservoir

Hydrological regime of Aparan reservoir is significantly affected by anthropogenic factors, i.e. the regulation and operation of the reservoir's daily, seasonal and multi-year modes of water resources. Stronger water level increase in reservoir is associated with spring floods, and the maximum level is observed in the end of spring and at the beginning of the summer. Mean water level increase consists of 21cm per day during the spring floods. As irrigation season begins, the accumulated water in the reservoir is intensively used and the water level is reduced (July-October). The filling of the reservoir begins immediately after irrigation season. However, due to low water in the rivers, total increment of water level consists of, on average, 1.8m, from November to March, i.e. approximately at a rate of 1cm per day (Միսակյան, 2011). In some years (1989, 2003), when the autumn rains were intense, the total increase of 350-400cm was recorded. The most severe episode of daily water level increase was observed March 5 - 6 of 2004 with the rate of 390cm per day. During those days mean daily temperatures were above normal values by 10-13^{0}C at Aparan meteorological station resulting in rapid snowmelt and water level increase of the reservoir. Aparan reservoir, in 1968-2017, was totally filled 8 times (1969, 1976, 1978, 1993, 2006, 2007, 2010 and 2011), while in some dry years water of Aparan reservoir was used for irrigation leading to decrease of water storage below the dead storage capacity level. The water level of Aparan reservoir mainly varies from 1812 to 1816m. Aparan reservoir, besides Kasakh river, collects water from the nine other rivers, the most prominent from which are rivers Gegharot, Ttujur, Kuchak, Eghipatrush (tabl.1).

Table 1

Mean monthly and annual inflows to the Aparan reservoir over 1968-2017

Rivers	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
	Water inflow volume, milion m^3												
Kasakh	1.24	1.20	3.22	10.4	9.29	4.62	1.92	1.33	1.41	1.42	1.41	1.34	38.8
Gegharot	0.65	0.56	0.86	1.84	3.45	5.50	5.45	2.55	1.40	1.09	0.85	0.87	25.1
Ttujur	0.27	0.27	1.15	4.45	3.34	2.45	0.71	0.45	0.22	0.33	0.36	0.25	14.3
Kuchak	0.16	0.19	0.61	1.87	0.74	0.28	0.26	0.19	0.19	0.21	0.24	0.22	5.16
Eghipatrush	0.17	0.19	0.53	1.67	1.81	1.15	0.54	0.34	0.12	0.32	0.38	0.24	7.46
	Lateral flow volume, milion m^3												
Entire catchment area of Aparan res.	0.84	0.82	1.88	5.53	4.71	2.21	1.12	0.74	0.46	0.84	0.83	0.81	20.8

It can be seen from Table 1 that the main river feeding the reservoir, is Kasakh River originating from Pambak mountain range at around 2200m (fig.1.a). The length of Kasakh River is 89km, and the basin area is 1480km^2. The absolute maximum discharge was recorded in Vardenis observation post of 151m^3/s (on 12.04.1972).The water inflow to the reservoir through the main rivers is determined using the data obtained from the hydrological observation posts located near the reservoir, while the lateral flow is determined using the empirical link, which was tested for the South Caucasus (Гидрометеорологический режим озер и водохранилищ СССР, 1985). Overall, Tab.1. shows that the peak in both water and lateral inflows is observed during the spring flood period (April-June) when water inflow consists of 45-65 % from the total water inflow.

Results

Forecast of spring maximum fullness level and water inflow

Statistical estimates of the relationships for reservoir's maximum fullness level and river inflow forecasts are presented in tab.2.

Table 2

Statistical characteristics of relationships for forecasting of Aparan reservoir's maximum fullness level (H_{max}, equation (1)) and water inflow ($W_{IV-VI\ Aparan}$, equation (2)) during spring floods over period 1968-2004

Parameter	Correlation coefficient, R	$\frac{S}{\sigma}$	$\pm 0.674\sigma$ (%)
H_{max}	0.91	0.41	91
$W_{IV-VI\ Aparan}$	0.86	0.52	81

Table 2 shows that the developed statistical relationships are characterized by quite high correlation coefficients and low RMSEs (relative to σ). Therefore, on the basis of the guidelines on hydrological forecasts (Руководство по гидрологическим прогнозам, 1989) the developed forecasting equations can be used in our further assessments of the components of water regime of Aparan reservoir. In order to validate the developed statistical methods of forecasting H_{max} and $W_{IV-VI\ Aparan}$ we evaluated forecasts of those hydrological parameters over independent period 2005-2017 (tab.3 and tab.4).

Table 3

The results of verification of Aparan reservoir's maximum fullness levels forecasts over 2005-2017, $\sigma_{permissible} = \pm 2.98, m$

Year	Maximum level, m		Bias, m (forecasts-observations)	Accuracy
	observed	forecasted		
2005	1832.65	1831.45	-1.20	justified
2006	1835.15	1835.61	0.46	justified
2007	1835.00	1832.26	-2.74	justified
2008	1824.35	1822.63	-1.72	justified
2009	1828.26	1827.87	-0.39	justified
2010	1835.19	1834.25	-0.94	justified
2011	1835.15	1830.79	-4.36	not justified
2012	1825.79	1826.58	0.79	justified
2013	1828.56	1826.48	-2.08	justified
2014	1821.22	1820.64	-0.58	justified
2015	1826.26	1826.77	0.51	justified
2016	1828.65	1824.67	-3.98	not justified
2017	1827.19	1826.96	-0.23	justified

It can be seen from table 3 that forecasts of H_{max} based on equation (1) are generaly underestimated relative to observations. However, in the most of cases we obtained successful forecasts, and only two forecasts (2011 and 2016) from 13 were out of permissible range estimated as $\pm 2.98\ m$ ($\sigma_{permissible}$). It is worth noting that very dry conditions prevailed in 2016, and precipitation amount at Aparan station in April was 35 % relative to norm.

Tab.4 presents the results of verification of reservoir's water inflow forecasts. Overall, the application of equation (2) produced successful water inflow forecasts, and significant deviations relative to observations are obtained for 2006, 2008 and 2014 when the magnitudes of forecast biases exceeded the permissible range estimated as $\pm 16.0, million\ m^3$. Again, 2008 and 2014 were characterised by significant dryness, and observed water inflows consisted of 19.0-20.0 million m^3. The significant negative bias was obtained for 2006 (- 48.9 million m^3). High water inflow observed during spring flood of 2006 was affected by significant amount of precipitation in beginning of the spring flood period, i.e. in April when monthly precipitation amounts exceeded the norm by three times, while precipitation amount for cold period (up to March) is considered in equation (2).

Table 4

The results of verification of Aparan reservoir's water inflow forecasts during the spring floods over 2005-2017, $\sigma_{permissible} = \pm 16.0, million\ m^3$

Year	Water inflow, million m^3		Bias, million m^3(forecasts-observations)	Accuracy
	observed	forecasted		
2005	75.5	63.2	-12.3	justified
2006	75.1	26.2	-48.9	not justified
2007	59.7	45.0	-14.7	justified
2008	19.0	48.7	29.7	not justified
2009	33.6	27.5	-6.1	justified
2010	33.0	48.7	15.7	justified
2011	63.9	49.0	-14.9	justified
2012	25.2	37.0	11.8	justified
2013	33.9	33.4	-0.5	justified
2014	20.4	4.4	-16.0	not justified
2015	35.3	33.4	-1.9	justified
2016	26.9	40.9	14.0	justified
2017	24.1	23.8	-0.3	justified

Climate change impact on hydrological regime of Aparan reservoir

The study area is greatly affected by climate change. The results of assessment of climate change impact over the catchment area based on observational data of Aparan station over 1935-2015 showed that the average annual air temperature has increased by 1.05^{0}C (the norm is 4.7^{0}C). Furthermore, since 1994 annual average temperature anomalies relative to norm were mostly positive (except for 2011). 2010 was the warmest year with positive temperature anomaly of 2.9^{0}C. It is worth noting that temperature increase is characterized by well-defined seasonality. Thus, the most significant temperature rise is observed in summer season, and the frequency of hot summer days were increased during the last 20 years (1998, 2000, 2006, and 2010). The precipitation amount changes are also characterised by different tendencies in different seasons. For instance, during 1935-2016, in Aparan reservoir's catchment area the precipitation amount is mostly increased, while in the autumn it was decreased by 20.1% relative to norm. In particular, the precipitation amount over 2011-2017 was abnormally low during the autumn months, leading to low spring floods. In order to assess climate change impact on characteristics of hydrological regime of Aparan reservoir during the 21st century we applied the developed equations presented in previous section. Climate variables included in equations (1) – (2) were derived from climate change projections of CCSM4 model already used in previous studies over Armenia (Կլիմայի փոփոխության մասին երրորդ ազգային հաղորդագրություն 2015, Gevorgyan et al., 2016). We selected the two high scenarios of climate change, namely

RCP8.5 (A2) and RCP6.0 (B2) scenarios. Thus, future changes in air temperature and precipitation for Aparan reservoir's catchment area is assessed for the 21th century and the results are presented in Tables 5 and 6. It can be seen from Table 5 that CCSM4 model predicts steady and significant temperature increase during the 21st century over the catchment area. In particular, temperature increase is much stronger during the summer, and summertime temperature increase can reach up to 6.0^{0}C at the end of century under RCP8.5 scenario. On the other hand, precipitation change projections are characterized by high variability and uncertainties with both precipitation increase and decrease in future (tab.6).

Table 5

Seasonal and annual air temperature norms (for reference period of 1961-1990) and changes (ΔT) over Aparan reservoir catchment during the 21st century according to the CCSM4 model under RCP6.0 (numerator) and RCP8.5 (denominator) scenarios

Periods	Winter	Spring	Summer	Autumn	Year
1961-1990 (norms, ^{0}C)	-7.2	3.8	15.8	6.6	4.7
2011-2040 (ΔT)	1.3/1.6	1.4/1.5	1.8/2.0	1.4/1.6	1.0/1.7
2041-2070 (ΔT)	2.7/2.7	2.5/2.8	3.0/3.9	2.4/3.3	2.8/3.4
2071-2100 (ΔT)	3.7/4.5	2.7/4.2	3.7/6.0	3.1/4.6	3.5/5.1

Table 6

Seasonal and annual precipitation norms (for reference period of 1961-1990) and changes (Δ, %)over Aparan reservoir catchment during the 21st century according to the CCSM4 model under RCP6.0 (numerator) and RCP8.5 (denominator) scenarios

Periods	Winter	Spring	Summer	Autumn	Year
1961-1990 (norms, mm)	137	226	222	138	723
2011-2040 (Δ, %)	7.4/-10.3	3.3/5.4	-14/-25	6.3/-0.6	1.2/3.9
2041-2070 (Δ, %)	5.8/15	4.4/1.0	-16/-8.0	3.2/10	-0.4/4.1
2071-2100 (Δ, %)	8.1/8.5	2.2/-1.1	-9.1/-30	-6.1/11	-0.4/-1.0

The results of vulnerability assessment of Aparan reservoir maximum fullness levels and river inflows associated with climate change are presented in tab.7.

Table 7

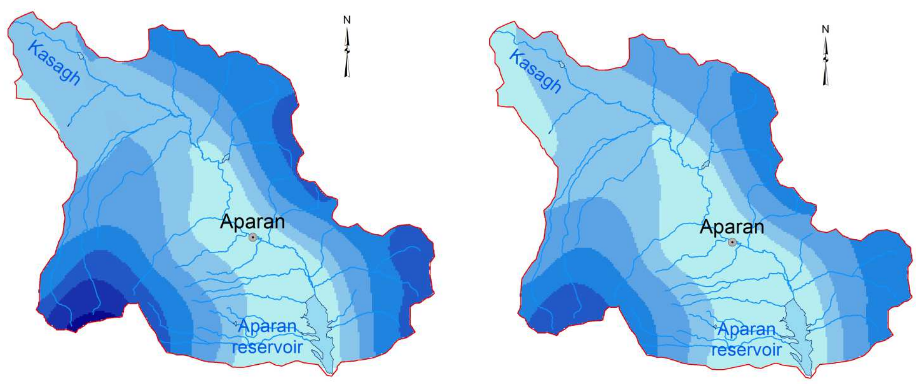
The results of vulnerability assessment of Aparan reservoir maximum fullness levels and water inflows during the spring flood period associated with future climate change

Parameters	Reference value	2040		2070		2100	
		RCP 6.0	RCP 8.5	RCP 6.0	RCP 8.5	RCP 6.0	RCP 8.5
H_{max}, *m*	1835.0	1827.7	1827.4	1824.5	1826.0	1825.9	1824.4
W_{IV-VI}, *mln m*^{3}	65.0	69.3	50.6	62.6	72.5	58.9	60.6

Tab.7 shows, that reservoir maximum fullness water level is expected to decrease in future due to significant temperature increase leading to increase in evaporation from the reservoir surface. The decrease in H_{max} reachs up to 11m through 2100 under RCP8.5 scenario. The latter will lead to reducing of the Aparan reservoir maximum capacity by 55–56 million m^3 compared to present maximum capacity (91 million m^3). By contrast there are high variablity and lower consistency in the results of vulnerability of water inflow. Thus, the results based on RCP8.5 scenario indicate water inflow decrease in 2040, then water inflow increase in 2070, while in 2100 it will decrease again. According to the RCP6.0 scenario in 2100 the water inflow will consists of 58.9 million m^3, which will be lower than the basis inflow by 6.1 million m^3. It should be noted that changes in water inflow are mainly depend on precipitation changes also characterized by quite variable regime during the 21st century (tab.6).

Finally, spatial analysis of vulnerabiltiy assessement of runoff depth during the spring flood over Aparan reservoir basin is presented in this study. The runoff depth is equivalent to mean water depth (mm) over the entire catchment area resulting from surface runoff. The spatial distribution of climatological (1961-1990) runoff depth over Aparan reservoir basin during spring floods is presented in fig.2.a) (Атлас природных условий и естественных ресурсов республики Армения, 1990). It can be seen from fig.2.a) that surface runoff depth is distributed inhomogenously over the cathcment caused by mountain topography. In particular, high surface runoff depths (400-600 mm) can be seen over high-elevated parts of the cathcment area characteraised by high snow cover, humidity and precipitation, while those over low-elevated areas are less than 100 mm. On the basis of estimated changes in W_{IV-VI} in future presented in Tab.7 spatial maps of river runoff were estimated for 2040, 2070 and 2100 (fig.2.b)-d)). It should be noted that only RCP8.5 scenario is considered here. Fig.2.b)-d) show that the surface runoff will experience both decrease (2040 and 2100) and increase (2070) in future associated with relevant changes in precipitation.

a) b)



c) d)

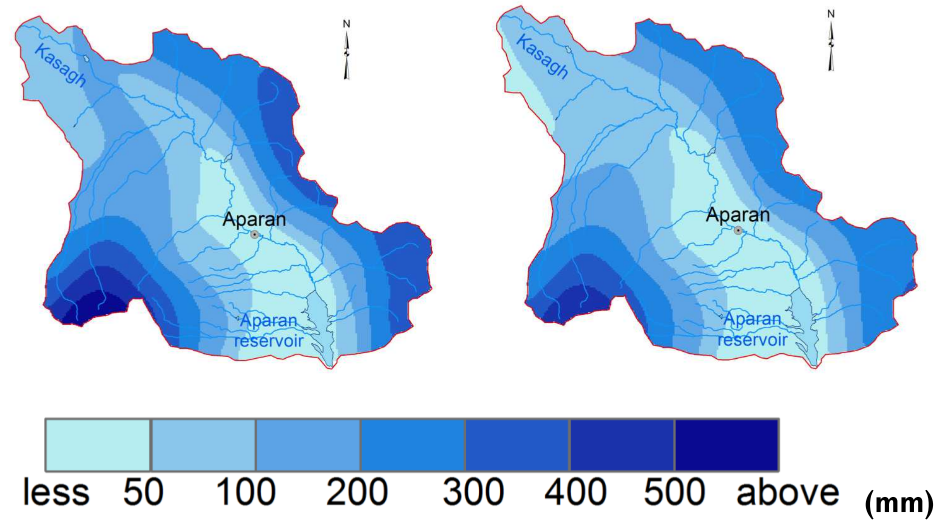


Fig.2. Climatological (1961-1990) and projected surface runoff depths (mm) over Aparan catchment area during spring floods. a) 1961-1990 (Атлас природных условий и естественных ресурсов РА, 1990), b) for 2040, c) for 2070, d) for 2100 (CCSM4 model, RCP 8.5 scenario)

Conclusions and discussions

The reservoir's maximum fullness water level is expected to decrease in future due to significant temperature increase, and the decrease can reach up to 11m by 2100 under RCP8.5 scenario. By contrast there are high variability and lower consistency in the results of vulnerability of water inflow and surface runoff depth attributed to the low consistency in precipitation projections derived from CCSM4 model. Further work on improving of assessment of water balance elements of the reservoir, hydrological modelling and examination of extreme hydrometeorological events should be considered in future. In particular, examination of changes of precipitation amount by precipitation types (liquid, solid and mixed) is expected to substantially improve our vulnerability assessment. It is obvious that temperature increase in future is expected to cause decrease in snow and increase in rain, leading to significant changes in the river flow and its pattern of seasonal distribution. Another important meteorological parameter affecting hydrological regime of Aparan reservoir is wind speed which is of great importance for adequate estimation of evaporation. Therefore, the above meteorological parameters should be considered in future works.

It should be noted that the results of this study are based on application of statistical model, while application of numerical hydrological models is expected to improve the assessment of water resources in Armenia. It is also an important issue to improve climate change projections using high resolution climate prediction models, e.g. The Coordinated Regional Downscaling Experiment (CORDEX) which would enable us capturing regional features of climate conditions over a mountain region like the studied basin.

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Կլիմայական տեղեկագիր II մաս, Օդի խոնավությունը, մթնոլորտային տեղումները և ձնածածկույթը, ՀՀ ԱԻՆ Հիդրոօդերևութաբանության և մոնիտորինգի պետական ծառայություն, 2011, Երևան, 172 էջ:

Կլիմայի փոփոխության մասին երրորդ ազգային հաղորդագրություն: Ըստ կլիմայի փոփոխության մասին ՄԱԿ-ի շրջանակային կոնվենցիայի: ՀՀ բնապահպանության նախարարություն, 2015թ., Երևան, Լուսաբաց, 190 էջ:

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Атлас природных условий и естественных ресурсов республики Армения. Гидрология. Академия наук РА, Институт геологических наук, отделение географии. Ереван 1990, 68с.

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Reviewer A.Arakelyan

ԱՊԱՐԱՆԻ ՋՐԱՄԲԱՐԻ ՀԻԴՐՈԼՈԳԻԱԿԱՆ ՌԵԺԻՄԻ ՎՐԱ ԿԼԻՄԱՅԻ ՓՈՓՈԽՈՒԹՅԱՆ ԱԶԴԵՑՈՒԹՅԱՆ ԳՆԱՀԱՏՈՒՄ

Ազիզյան Լ.Վ., Գևորգյան Ա.Մ., Միսակյան Ա.Է., Դանիելյան Ա.Գ., Ազիզյան Հ.Հ.

Ամփոփում

Աշխատանքը նվիրված է Ապարանի ջրամբարի հիդրոլոգիական ռեժիմի ուսումնասիրմանը և կլիմայի փոփոխության պայմաններում դրա խոցելիության գնահատմանը: Գարնանային վարարումների ընթացքում ջրամբար գետային ներհոսքի և առավելագույն լցվածության մակարդակի կանխատեսման համար օգտագործվել է ֆիզիկավիճակագրական մեթոդը և մշակվել են բազմագործոն ռեգրեսիոն կապեր: Մշակված կապերով և Կլիմայական Համակարգի Մոդել 4-ից (CCSM4) վերցված արդյունքներով գնահատվել է կլիմայի փոփոխության ազդեցությունը ջրամբարի հիդրոլոգիական ռեժիմի վրա: Համաձայն արդյունքների, դիտվում է կլիմայի փոփոխության նկատմամբ բարձր խոցելիություն: Մասնավորապես, կանխատեսվում է ապագայում ջերմաստիճանի զգալի աճի հետևանքով ջրամբարի առավելագույն լցվածության մակարդակի նվազում, որը 2100թվականին համաձայն RCP8.5 սցենարի արդյունքների կարող է հասնել մինչև 11մ: Իսկ գետային ներհոսքի և հոսքի շերտի բարձրության խոցելիության արդյունքներում առկա է մեծ փոփոխականություն և ցածր կայունություն՝ կապված տեղումների կանխատեսումների մեծ անորոշությունների հետ:

- Հետազոտությունն իրականացվել է ՀՀ ԿԳՆ գիտության պետական կոմիտեի տրամադրած ֆինանսավորմամբ՝ «Սևանա լիճ և ՀՀ խոշոր ջրամբարներ գարնանային վարարումների ընթացքում գետային ներհոսքի և առավելագույն մակարդակների կանխատեսումները կլիմայի փոփոխության պայմաններում» 16YR-1E071 ծածկագրով գիտական թեմայի շրջանակներում:

ОЦЕНКА ВЛИЯНИЯ ИЗМЕНЕНИЙ КЛИМАТА НА ГИДРОЛОГИЧЕСКИЙ РЕЖИМ ВОДОХРАНИЛИЩА АПАРАН

Л.В.Азизян, А.М.Геворгян, А.Э.Мисакян, А.Г.Даниелян, А.О.Азизян

Резюме

В статье рассматривается гидрометеорологический режим Апаранского водохранилища и его уязвимость в условиях изменения климата. Разработаны статистические модели для прогнозирования речного притока и уровня максимального наполнения водохранилища. Данные полученные из модели климатической системы сообщества 4 (CCSM4) ис-

пользовались для оценки влияния изменения климата на гидрологический режим Апаранского водохранилища. Результаты показывают высокую уязвимость к изменению климата. В частности, ожидается, что в будущем из-за значительного повышения температуры, уровень максимального наполнения водохранилища уменьшится, и это снижение уровня может достигнуть 11 м до 2100 согласно сценарию RCP8.5. Однако, в связи высокой неопределенностью в оценках изменения осадков, существует высокая изменчивость и более низкая согласованность в результатах уязвимости речного притока воды и слоя стока.

- Исследование выполнено при финансовой поддержке Государственного комитета по науке МОН РА в рамках научного проекта № 16YR-1E071 - «Прогнозирование речного притока в озеро Севан и крупные водохранилища РА, их максимальных уровней во время весеннего половодья в условиях глобального изменения климата».