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AGRICULTURAL WATER REQUIREMENT SUPPLY UNDER CLIMATE CHANGE (CASE STUDY: BAZOFT RESERVOIR)

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Abstract. In the present study, the effect of climate change on the water demand of the agricultural sector of Bazoft Reservoir was investigated. In this study, the base period (1971-2000) was considered and the climate variables in the future period (2040-2069) were simulated by the CanESM2 model (under RCP2.6, RCP4.5 and RCP8.5 emission scenarios). became The calculation of temperature and rainfall in the future period under all three emission scenarios shows that the long-term average monthly temperature will increase in the two future periods compared to the base period. ANN model was used to estimate the inflow into the reservoir and the results showed that the inflow into the reservoir will decrease in most months during the coming periods. Since the estimation of agricultural water demand has been one of the main goals of this research, the FAO-Penman-Monteith equation was used and the results indicate that the water demand in the agricultural sector will face an increase in the future periods compared to the base period. In the end, PSO optimization algorithm was used to determine the exploitation rule and the results showed that in the future period, the exploitation rule resulting from the combination of the Fao-Penman-Monteith equation and the ANN model (under the RCP4.5 scenario) has the highest reliability criterion. Acceptability (91.55) and the least vulnerability criterion (6.82 percent), has the best performance in meeting water demand.

Keywords: climate change, 5th report, Bazoft, CanESM2 model

1. INTRODUCTION

Since the beginning of the industrial revolution until now, which has been accompanied by the growth of industries and factories and consequently the consumption of fossil fuels, mankind has witnessed the destruction of forests and pastures and the change of agricultural land use, all of which are caused by the activities of It is human-made and has caused excessive release of greenhouse gases in the atmosphere. It should be mentioned that if the current trend of fossil fuel consumption continues, the concentration of this gas can reach more than 600 ppm by the end of the 21st century (IPCC, 2007a). This increase causes more absorption of infrared waves emitted from the earth by greenhouse gases, which leads to the warming of the earth. The warming of the earth also affects the state of the climate system and causes the phenomenon of climate change (Baede et al., 2001). Among the evidences of climate change, except for the change in the pattern of precipitation and the increase in the temperature of the earth, we can see the intensification of phenomena such as floods, droughts and heat waves, the rise of the ocean water level due to the melting of glaciers. And he mentioned the change in the amount of evaporation and transpiration during the growth period of plants. The phenomenon of climate change is one of the biggest sources of uncertainty in the long-term planning horizon in hydrological and meteorological processes. The term climate change refers to long-term changes in the possible distribution pattern of meteorological phenomena (Ashofte, 2013). These changes can span periods of 10 years to a million years. In general, the two main pillars in water resources management are estimating the amount of water demand and forecasting the state of water resources. Climate change affects water consumption. Therefore, it is necessary to consider the change in water demand due to climate change in the management of water supply projects. Considering the changes in the amount and temporal distribution of water resources in the climate change conditions, as well as the changes in water demand in the agricultural sector (which account for the largest share of consumption) and also, The reason for the very high cost related to the development plans of water resources and water use, it is necessary to manage both water resources and water use in an optimal way with the aim of maximum water efficiency and maintaining the satisfaction of the stakeholders. Therefore, in order to present a picture of the possible situation of water resources and consumption in the future period, it is necessary to include the effects of climate change in any long-term planning (Ashofte, 2013). Therefore, all the factors and parameters affecting a water resources system should be considered for proper management. The parameters affecting the volume of water stored in the reservoir as a part of a water resources system include: the amount of precipitation, river flow, evaporation from the free water surface, leakage from the walls and bottom of the reservoir, and the release amount to meet the needs. After determining these parameters, the volume of water stored in the reservoir of the dam is determined, and according to the goals, prioritization of needs and using optimization methods, the optimal policy of operating the system is adopted. On the other hand, the use of simulation models is the easiest method for exploiting dam reservoirs, which is why they are preferred over optimization models in most cases.

In this research, the effects of climate change on the quantitative and qualitative variables of water in the Bazoft dam reservoir have been investigated and evaluated. In climate change studies, climate forecasting is done by atmospheric general circulation models and under greenhouse gas emission scenarios. Considering that the output of these models are large-scale parameters and lack spatial and temporal accuracy suitable for use in regional studies, micro-scale models should be used to apply climate change studies. For this purpose, microscaling methods of climate studies have been investigated and evaluated, and the considered method has been explained in this research. In the next step, greenhouse gas emission scenarios have been examined. Then, a runoff prediction model has been introduced, and the outputs of the general atmospheric circulation model, which includes (maximum temperature, minimum temperature, and precipitation) have been used as input data for the hydrological model, as well as the volume of water demand for the products under The cultivation of the studied reservoir basin has been investigated and at the end, the method of deriving the optimal exploitation rules from reservoir has been investigated.

2. MATERIALS AND METHODS

2.1. The investigated area

Karun River is considered as the most important and abundant source of surface water in the country. The catchment area of this river is located in the geographical coordinates of 49°:35' to 50°:35' east longitude and 31°:40' to 32°:40' north latitude. The watershed of Karun river is located in the west of the country and this The river originates from the highlands of Zagros (southwest of Isfahan province). So that after connecting the surface currents of Junaqan River and joining Kohrang River, Karun River is formed. In the continuation of the course of Ab Vanak River, it joins Karun in Armand, and after the addition of Sarkhoon, Bazoft, Lordegan and Khersan tributaries, the great Karun River is formed. This watershed is limited to Golpaygan and Zayandehroud watersheds from the north, Karkhe and Dez watersheds from the west, Zayandehroud and Ker from the east, and the Maroon, Zohreh, and Jarahi Rivers watersheds from the south. In this study, Bazoft reservoir is selected.

2.2. Data used by Bazoft reservoir

Temperature: The average monthly temperature in the study area is below zero degrees Celsius in January and reaches a minimum value of -1.93 degrees Celsius. In other months of the year, the long-term average monthly temperature is above zero degrees Celsius and in the summer season it reaches the maximum value of 25 degrees Celsius.

Rainfall: Checking the average monthly rainfall at the watershed reference station (Shahrkord station) shows that in the last month of winter and the first months of spring, the rainfall is more than 40 mm. March and April are among the rainy months. On the other hand, it can be seen that similar to the climatic condition of other regions of Iran, most of the rains were in winter and spring, and the amount of rain in summer is close to zero. Rainfall in the region in the months of January and February, due to the temperature close to zero in these months, will mainly be in the form of snow..

Runoff: According to the information recorded by the meteorological station, the maximum monthly rainfall is about 60 and 50 million cubic meters in the months of April and May, respectively. It can be said that on average 60% of the annual flow is related to these months. The seasonal flow distribution of this river in spring, summer, autumn and winter seasons is 65, 1.4, 10.2 and 23.4 percent of the annual flow volume, respectively.

Figure 1. Karun watershed map

2.3. AOGCM models

In this model, the variables related to the general circulation of the atmosphere and the ocean have been taken into consideration. Also, in this model, the interrelationships of the main climate systems have been considered, which are:

1- Interrelationships between terrestrial and atmospheric ecosystems
2- Interrelationships between land and ocean ecosystems
3- Interrelationships between oceanic ecosystems and the atmosphere

Also, in this model, the physical and chemical characteristics of the atmosphere and human systems and the resulting changes on climate variables have been considered.

In this research, the general circulation model of the atmosphere (GCM) has been used in order to model the climatic variables and make predictions on the considered climatic elements. In the flowchart of Figure 2, the classification of climate modeling methods is shown.

One of the main limitations in using the climatic outputs of general cycle models is that the accuracy of their spatial and temporal decomposition does not match the required accuracy of regional and hydrological models. The spatial accuracy of these models is around 200 km, which is not suitable especially for investigating mountainous areas and climatic parameters such as precipitation and temperature. By using the downscaling method, the outputs of these models can be converted into surface variables at the scale of the studied area.

In this research, the 1971-2000 period was considered as the base period, and the 2040-2069 period with the characteristic (2050) was chosen as the future period. Usually, the investigation of the effects of climate change on the systems is done according to a long-term horizon plan, and this caused the future period to be considered with a long-term period in this study. In addition, the courses were chosen according to the recommendation of the Meteorological Organization. After determining the basic and future periods, to show the uncertainty resulting from different AOGCM models, the outputs of six AOGCM models in the basic and future periods, from the IPCC website and according to the Fifth Assessment Report (FAR) were obtained The obtained outputs of the models included the daily average of two important climatic parameters, precipitation and temperature.

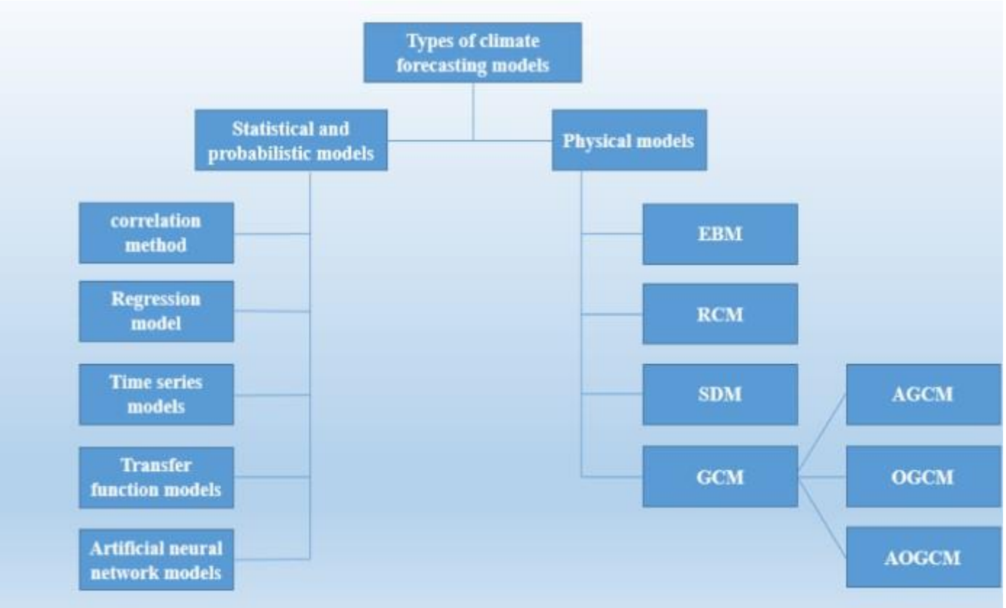

Figure 2. Flowchart of various climate forecasting models

2.4. FAO-Penman-Monteith method

FAO-Penman-Monteith method, which is one of the most reliable methods for estimation ET_0 . FAO has proposed this equation as a standard method for calculation ET_0. Due to the high accuracy of the mentioned method, this method has been used for calculation ET_0 in this research. The FAO-Penman-Monteith equation is as follows (Allen et al., 1998):

$$(1) \qquad ET_0 = \frac{0.408 \times \Delta_t \times (R_{nt} - G_t) + \Upsilon_t \times \frac{890}{T_{ave}+273} \times U_{2m} \times (e_{st} - e_{at})}{\Delta_t + \gamma_t (1 + 0.34\, U_{2m})}$$

where in :

ET_0 = reference evapotranspiration (mm/day),
R_{nt} = net radiation input to the surface of the plant in the month $(\mathrm{MJ/m^2/day})$
G_t = soil heat flux per month $(\mathrm{MJ/m^2/day})$
T_{ave} = Average air temperature (°C) during the period,
U_{2mt} = Wind speed at a height of two meters (m ⁄ s)
e_{st} = Saturated vapor pressure (KPa),
e_{at} = True vapor pressure (KPa),
$(e_{st} – e_{at})$ = Lack of saturation vapor pressure in the month t (KPa),
D_t = The slope of the saturation vapor pressure curve with temperature in the month t (KPa⁄°C),
g_t = Constant coefficient of psychrometry in month t (Kpa ⁄ °C),
890 is the coefficient for the reference plant (kg ⁄(kJ/day)) and 0.34 is the wind coefficient for the reference plant (sec ⁄ m).
Also, the method of calculation e_{st} and e_{at} is shown in relations 2 and 3.

$$(2) \quad e_{st} = \frac{0.611 \times e^{\frac{17.27 \times T_{\min t}}{T_{\min t}+273}} + 0.611 \times e^{\frac{17.27 \times T_{\max t}}{T_{\max t}+273}}}{2}$$

(3) $e_{at} = \frac{RH_t}{\frac{50}{(e_{at})_{T\max t}} + \frac{50}{(e_{at})_{T\min t}}}$

where,
RH_t = the relative humidity in the month (%)
$(e_{at})_{T\max t}$ and $(e_{at})_{T\min t}$ represent the real vapor pressure in the maximum and minimum temperature in the month of t, respectively.

It is possible to estimate the irrigation requirement by having plant evaporation and transpiration values (ET_c) and effective precipitation ($P_{eff\ t}$).

Effective rainfall is that part of the total rainfall during the growing season of the crop that provides the plant's water needs. In this research, the effective precipitation is calculated using the method of United States Soil Conservation Service (SCS) and using Cropwat software. The relationships used in this software are presented below.

(4) $P_{eff\ t} = \left(P_t/125\right) \times (125 - 0.2P_t) \qquad P_t \leq 250\ mm$

(5) $P_{eff\ t} = 125 + 0.1P_t \qquad P_t \geq 250\ mm$

in them, $P_{eff\ t}$ the effective rainfall is in the month of t.
Now the net need of irrigation in each month is calculated according to equation 6 from the difference of ET_c and $P_{eff\ t}$.

(6) $IR_t = ET_{ct} - P_{eff\ t}$

In which, IR_t the net irrigation requirement is in the month of t. In the following, having the values of irrigation needs of the crops in the next period, the amount of water demand is obtained according to the cultivated area of each crop and according to equation .

(7) $V_t = A_c \times IR_t$

where , A_c the cultivated area of each crop and V_t the amount of water demand in month t.

3. RESULTS AND DISCUSSION

3.1. Check the validity of the model created to predict temperature and precipitation parameters

In this study, the daily observation data of average temperature, maximum temperature, minimum temperature and daily precipitation in the period of 1971-2000 were entered into the model as input, and with the help of SDSM model, the daily data of the mentioned meteorological variables were produced in the same period. Comparison of the observed and produced monthly averages of meteorological variables of precipitation , minimum and maximum temperature and average daily temperature using statistical parameters RMSE, R^2 showed that the model had the necessary efficiency to generate daily data of the parameters mentioned in the study area. And it is possible to predict meteorological data of precipitation, minimum and maximum temperature and average daily temperature by using this model by designing a scenario.

In the graphs of Figure 3 and 4, the average observed and simulated data, related to the average temperature and precipitation, are displayed respectively.

According to Figure 3, the results obtained from the model prediction have been compared and verified with the results obtained from the temperature observation data. The red curve and graph represent the observational data and the green curve and graph represent the results of the prediction model created for the temperature in the same time period. According to Figure 3, it is clear that the created forecasting model has acceptable accuracy and the existing graphs and curves have a suitable overlap to use the model for long-term temperature forecasting.

Figure 4 shows the validity of the prediction model created compared to the observational data of precipitation for the same time period (base period). Due to the fact that the phenomenon of precipitation is highly conditional and has a nonlinear regression simulation, and the prediction of precipitation has more complexities than temperature. The results obtained from the created model compared to the observational data have a good accuracy and this model can be used to predict the amount of long-term rainfall. According to figures 3 and 4, it can be seen that the graphs of the observed and simulated data in the base period are almost close to each other and equal to each other. (except in some months of June, August and September) and this confirms the accuracy of the model's ability to predict the climatic parameters of temperature and rain in the future.

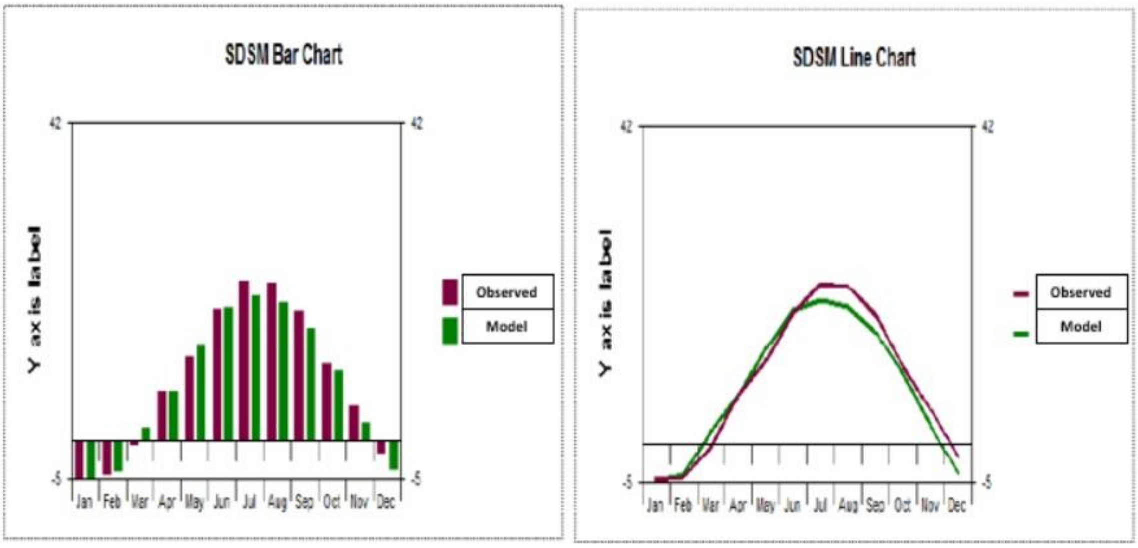

Figure 3. Average temperature graph of observed and simulated data during the observation period

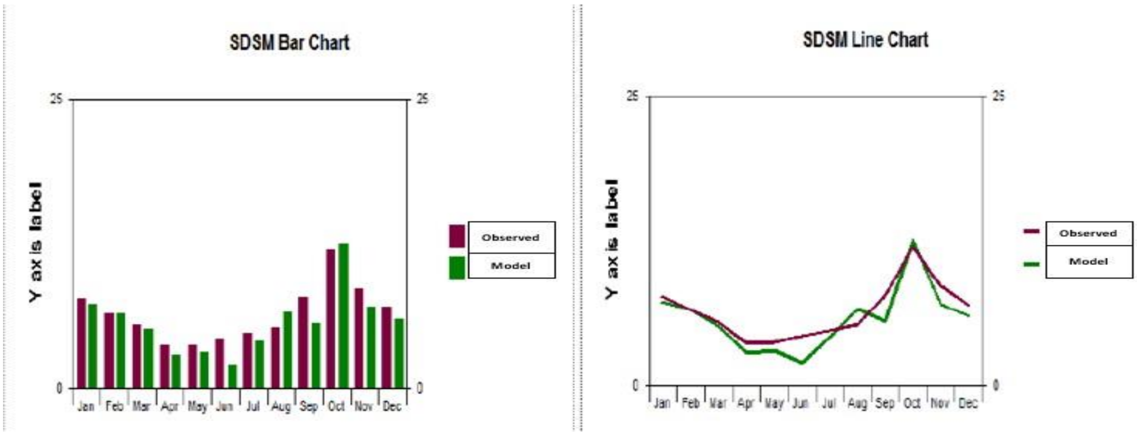

Figure 4. Average precipitation diagram of observed and simulated data in the observation perio

3.2. Optimization process

In this section, the results obtained from the extraction of the rules for the use of the reservoir in the future periods are examined, which are simulated using the SOP rules and optimized by the PSO algorithm. By entering the volume of agricultural demand, the volume of flow entering the reservoir and the volume of evaporation, It is possible to estimate the monthly values of the release volume from the tank, the tank storage volume, the overflow volume and the shortfall volume to meet the need for future periods. In this section, for a better understanding of the contents, three scenarios are defined:

- The first scenario: under the RCP2.6 climate scenario and calculated from the combination of the Penman-Monteith relationship and the ANN model
- The second scenario: under the RCP4.5 climate scenario and calculated from the combination of the Penman-Monteith relationship and the ANN model
- The third scenario: under the RCP8.5 climate scenario and calculated from the combination of the Penman-Monteith relationship and the ANN model

In the following, the results related to the optimization of the release volume from the tank in three different scenarios are presented. Figures 5 to 7 show the results of the long-term average monthly release volume from the reservoir (in the first, second, and third scenarios) in the future period (2040-2069).

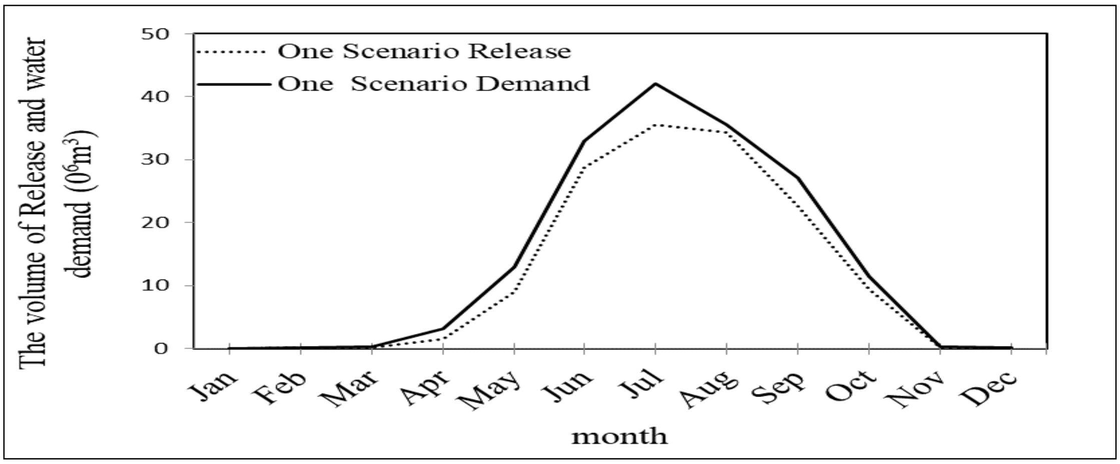

Figure 5. Long-term average monthly release volume and water demand of the first scenario in the future period

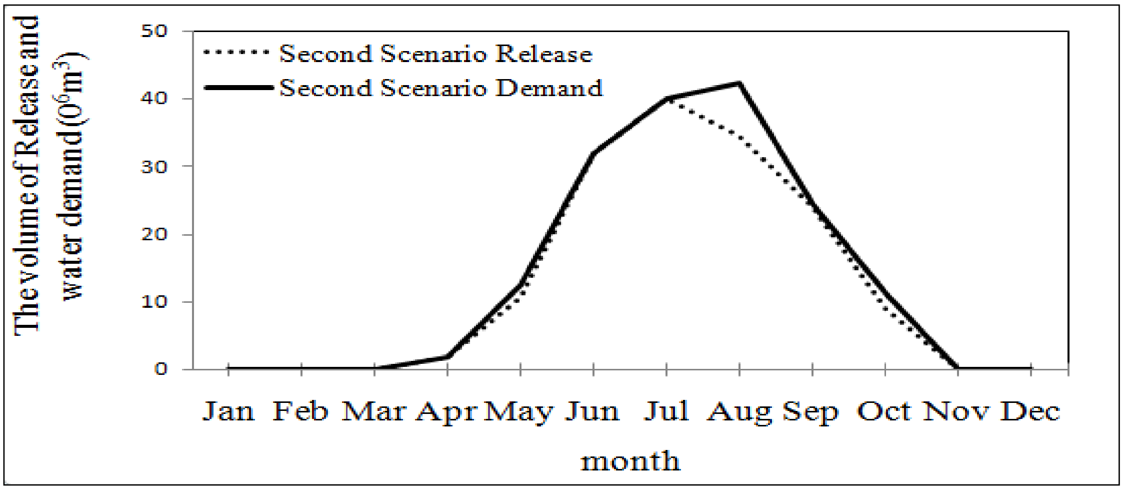

Figure 6. Long-term average monthly release volume and water demand of the second scenario in the future period

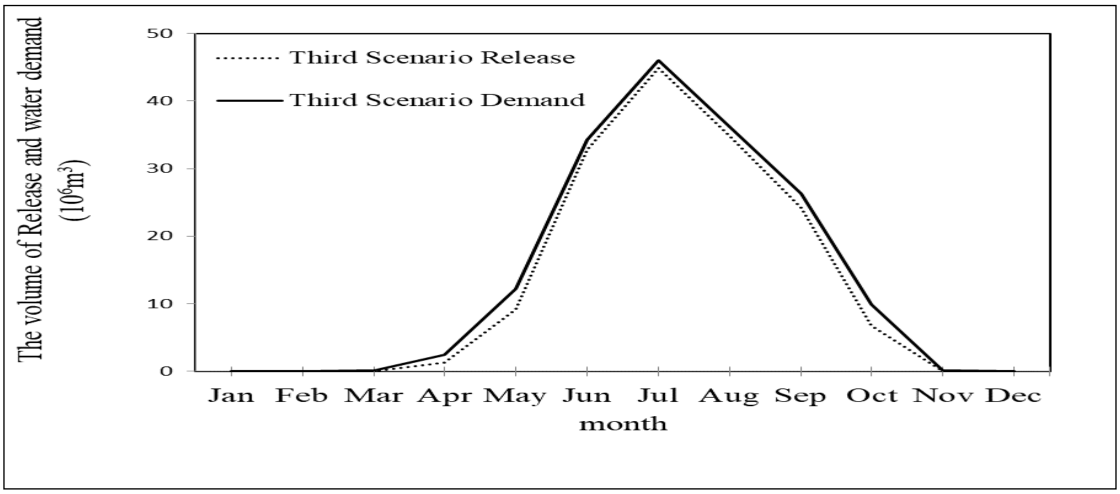

Figure 7. Long-term average monthly release volume and water demand of the third scenario in the future period

As can be seen in the figures, in the first scenario, the peak release is in July, in the second scenario, in July, and in the third scenario, in July. It can also be seen that the second scenario is more successful than the other scenarios by providing 91.557% of the demand. After that, the third scenario provided 91.195% and the first scenario provided 82.715% of the demand.

3.3. Performance criteria

In this section, to check the performance of the reservoir in meeting the demand and according to the volume of water available, the efficiency criteria are compared in the three scenarios that have been defined. Table 2 shows the relevant results in the upcoming period.

scenario	Reliability(%)	Reversibility(%)	Vulnerability(%)	Flexibility(%)
first	82.71	30.18	8.09	25
second	91.55	38.41	6.82	33
third	91.19	27.59	10.42	22

Table1 2. Comparison of performance criteria in three scenarios in the future period

Table 2 compares the efficiency criteria in the future period (2040-2069) in three scenarios. In this table, it can be seen that the second scenario with the highest percentage of reliability (91.55), the highest percentage of reversibility (38.41), the lowest percentage of vulnerability (6.82) and finally The highest percentage of flexibility (33) has a better performance than other scenarios in estimating the water demand of the studied area.

4. CONCLUSION

In general, in the present study, the effect of climate change on the agricultural water demand of Bazoft Reservoir was investigated. In this study, the base period considered was the period (1971-2000) and the climate variables in the future period (2040-2069) were simulated by the CanESM2 model (under RCP2.6, RCP4.5 and RCP8.5 emission scenarios). The calculation of temperature and rainfall for the future period was carried out under all three emission scenarios RCP2.6, RCP4.5 and RCP8.5 and it was observed that the long-term average monthly temperature in the future period will increase compared to the base period. Also, the results of estimating the inflow into the reservoir with ANN model showed that the inflow into the reservoir will decrease in most months in the coming period. On the other hand, the investigations related to the estimation of agricultural water demand with the FAO-Penman-Mantis relationship also showed that the water demand in the agricultural sector will face an increase in the future periods compared to the base period. It also showed optimization with PSO algorithm in the future period (2040-2069), the exploitation rule resulting from the combination of Faupenmann-Monteith relationship and ANN model (under RCP4.5 scenario), with the highest reliability criterion (91.55) and the least vulnerability criterion (6.82 percent), has the best performance in providing water demand.

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