Flow regime changes of Gamasiab River under climate change scenarios

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Expanded Abstract

Introduction

In the recent decades, temperature has increased and rainfall has changed significantly. Based on the Intergovernmental Panel on Climate Change (IPCC) surveys the average temperature of the earth has grown about 0.6°C in the twentieth century. Understanding the impacts of these changes on watershed hydrology is important for human society and ecological processes. Nowadays, with releasing fifth series of General Circulation Models (GCMs) by IPCC, new researches have been focusing on the effects of climate change by statistical downscaling of CMIP5 models. Potential impacts of climatic changes on aquatic ecosystems species, nutrient delivery, temperatures and hydrology have been studied. In addition, the effects of climate change on hydrology have been examined in many studies using the CMIP5 series to study the stream changes in global scale under climate change conditions. These studies indicated if the greenhouse gas emissions are continued, available water levels will be reduced. The amount of hydrological impacts of climate change is varying based on different RCPs. In some studies, the greatest change in the rate of large flooding reported under RCP2.6 and the smallest changes under RCP4.5. Further studies indicate more floods occurrence under RCP8.5.
The first effects of climate change are visible on temperature and precipitation; changing these variables will disrupt the current order of the hydrological cycle. The new state of the hydrological cycle causes a change in the flow regime. Natural flow regime plays a major role in sustaining native biodiversity and ecosystem integrity in rivers. Characterization of flow regime has been examined by some researchers via metrics that describe the magnitude, frequency, duration, timing and rate of change for stream flow.
The Gamasiab River watershed is one of the five main branches of the Karkheh River in the west side of Iran; it plays an essential role in preserving the life and ecosystem of this area, so preserving the quality and quantity of water in this river is of great importance. We perform such an assessment in the Gamasiab River watershed, and subsequently project future flow regime for the Gamasiab River using the downscaled climate data using metrics that are useful to policymakers and ecologists.

Material & Methods

The Gamasiab River watershed is located between Hamedan, Kermanshah and Lorestan provinces. The watershed area is about 11690 km^2, with 515816 hec of agricultural land, 619583 hec of pasture, 4938 hec of urban land, and 28663 hec of others lands.
In this study, the SWAT model was used to simulate flow discharge. The SWAT model needs three maps to simulate discharge including Digital Elevation Map (DEM), soil and land use map. This model divides sub-basins into a number of Hydrologic Response Units (HRUs), each HRU is the main simulation unit in the SWAT

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model (30). Daily precipitation (Pcp), minimum and maximum air temperatures (Tmin and Tmax) for the period from 1977 to 2005 were obtained. The daily discharge in the Polchehr hydrometric station during the years 1977 to 2005 were used for calibration of the model as well as the comparison of changes in flow regime under climate change conditions.
Optimization of parameters and uncertainty analysis of the SWAT model were performed by using SWAT-CUP software by the SUFI2 algorithm (Sequential Uncertainty Fitting Ver. 2).
In order to simulate and predict the effects of climate change in the future, General Circulation Models (GCM) were used. The main problem in using general circulation models in regional research is their large scale. There are various methods for producing regional climate scenarios from these models, which called downscaling. In this research the Change Factor Mean-Based Method was used to downscaling CMIP5 models.
The flow regime and its changes were studied under conditions of climate change for high flow disturbance and low flow disturbance distribution. The distribution of high flow was investigated by using three indexes including 7-day maximum flows (7QMAX), a high discharge distribution (Q1.67) and flood duration (FLDDUR). A seven-day minimum flow (7QMIN) parameter was used to investigate the distribution of low flows. The Daily Flow Coefficient of variation was also used to show the overall changes of the flow regardless of the time series. 7-day maximum flows are the average of maximum daily discharge of seven days per year. For this purpose, the moving average of the daily discharge in seven-day is calculated for each year and the biggest one selected as 7-day maximum flows of the year. The Q1.67 index is defined as flow of magnitude exceeding a return interval of 1.67 years based on a log-normal distribution. Flood duration (FLDDUR) is also the average number of days per year when flow equals or exceeds Q1.67. Seven-day minimum flows are the average of minimum daily discharge of seven days per year. The Kernel probability density graph was used to show the flood duration for observational data and scenarios

Results

In this study, the model was calibrated to daily stream flows at the watershed outlet. To perform sensitivity analysis and evaluation of the model, SUFI2 algorithm in SWAT-CUP software was also used. Model performance was assessed using the Nash–Sutcliffe efficiency metric on daily flows (NS).
Change factor method was used for downscaling the CSERO-K3.6.0 model. Rainfall data and minimum and maximum temperatures were obtained under two scenarios RCP2.6 and RCP8.5 for the periods 2049-2020 (near future) and 2050-2099 AD (far future).
To study the flow regime changes under RCP2.6 and RCP8.5 scenarios for the period 2020-2020 (near future) and 2050-2099 AD (far future), the calibrated SWAT model for the Gamasiab basin, run again by using downscaled data from CSIRO-Mk3-6-0 model including the minimum and maximum daily temperature and the daily precipitation. The results of future flow simulation in the Gamasiab basin show that based on RCP2.6 the mean of the discharge will be close to 36.6 m^3/s in the near future, which is slightly more than the mean of the discharge in observation period (33.1m^3/s). Continuing this scenario would increase the average of discharge by 17.8% and reach to 40.4m^3/s in the future. The average discharge under RCP8.5 will be reduced to 30.6m^3/s in the near future, and the continuation of the RCP8.5 in the far future will cause a very sharp decrease in average of discharge and reach 19.1 m^3/s.
We assessed climate induced-changes in flow disturbances. The 7QMAX changes under RCP2.6 in the near future show the same trend by comparing observation period. The average of 7QMAX in the observation period is 209 m^3/s. Under the RCP2.6, the average of 7QMAX in the near future will reach 154.4 m^3/s, and in the far future it will reach 183.7m^3/s. The 7QMAX under the RCP8.5 will be reduced in the near and far future. The average 7QMAX in the near future will be close to 146/6 m^3/s, and in the far future it will reach 96.8 m^3/s.
The 7QMIN in the near and far future will a little change compared to the observation period. The average of 7QMIN in the observation period is 2 m^3/s, and this average under RCP2.6 for the near and far future will be 1.2 and 1.6 m^3/s respectively. Under the RCP8.5, 7QMIN will be significantly reduced, with an average of 0.9 m^3/s in the near future and 0.48 m^3/s in the far future. With the fitting of the log-normal distribution, the maximum instantaneous velocity of the discharge was calculated with a return period of 1.67 years, thus the value of Q1.67 was calculated 211.29 m^3/s. To calculate the flood duration in each year, the number of days which flow was equal to or greater than Q1.67 was counted. According to the kernel density diagram, during the observation period and the selected scenarios, flood events with a maximum of 5 days' duration are most likely to occur. It is also observed that under RCP2.6, in the near and far future, the probability of occurrence of floods with longer duration is expectable.

Discussion

The study shows that the Gamasiab River watershed is flashy. Under the scenario RCP2.6, which is a favorable scenario with minimal greenhouse gas emissions, the coefficient of variation will be reduced significantly. It can

be concluded that in addition to increasing the average of the runoff under RCP2.6, the flash floods of the river will reduce. In this regard, under the scenario RCP8.5, more floods in the Gamasiab River watershed were occured.
The 7QMAX and 7QMIN in all scenarios will decrease compared to the observation period. In both indexes, the lowest decreases are under RCP2.6 in far future, and the largest decline is under RCP8.5 in the far future.
The kernel chart in observation period shows that the duration of floods occurrence most likely is maximum 5 days. Under RCP2.6, in the near future floods with a maximum duration of 5 days are the most likely to occur but are less than the observation period, instead of under RCP2.6 10 to 15 days of floods duration are more than the observation period. Base on this chart, it can be concluded that under the scenario RCP2.6, the duration of the floods will be increase compared to the observation period, and it will be longer in the end of this century. The results under the RCP8.5 scenario indicate that the flood duration in the near future will be dramatically reduced and at the end of the current century, the flood frequency with a discharge equal to or greater than Q1.67 will be sharply reduced.

Conclusion

The results of this study indicate that the flow regime will change under different scenarios in the upcoming period. The intensity of these changes in far future (the end of this century) will be greater than in the near future. It can be concluded that under RCP2.6 watt/M^2 forcing scenario will have no significant changes in the amount of available water in the near future, but the continuation of this trend in the far future causes to increase the average of discharge along with reducing the risk of flooding. It is a great indication that the future situation is favorable if this trend continues. Increasing radiative forcing to the RCP8.5 watt/M^2 level in the near future addition to reduce the average discharge, the risk of large flood events increases, and the continued increase in greenhouse gas emissions in the far future will be result in a very severe decrease in the average discharge, then water availability will be reduced.

Keywords: flow regime, CMIP5, Gamasyab, SWAT.