RESEARCH ARTICLE

Climate change simulation and impacts on extreme events of rainfall and storm water in the Zayandeh Rud Catchment

Safieh Javadinejad[1*] **Rebwar Dara**[2] **Forough Jafary**[3]

[1] Département of Civil Engineering, Université du Québec à Montréal, Canada
[2] Department of Environmental Engineering, College of Engineering, Knowledge University, Kurdistan Region, Iraq
[3] Water Resource Management, Environment Agency, UK

Correspondence to: Safieh Javadinejad, Departement of Civil Engineering, Université du Québec à Montréal, Canada;
Email: javadinejad.saf@ut.ac.ir

Abstract: Nowadays, one of the most significant problems is that to recognize how the severity of heavy precipitation and floods may alter in future time in comparison with the current period. The purpose of this research is to understand the impact of future climate change on storm water and probability of maximum flood for future time period. Zayandeh rud river basin in Iran is selected as a case study. Forecast of future climatic parameters based on temperature and precipitation of the upcoming period (2006-2040) is completed with using the HadCM3 model and based on RCP 2.6, 4.5, and 8.5 emission patterns. Also, climate change model is downscaled statistically with applying LARS-WG. In the next step, the probable of maximum precipitation is measured through synoptic method and then, in order to model maximum storm water under the climate change effects, the HEC-HMS for simulating rainfall-runoff model is used. Also, the Snowmelt Runoff Model (SRM) is applied to model snow melting. The results of this research indicate the maximum of probable precipitation in the basin for the period of 2006-2040 under the scenario RCP 2.6, can rise by 5% and by the scenarios of RCP 4.5 and RCP 8.5 can decrease by 5% and 10%, respectively in comparison with the current period 1970-2005.

Keywords: climate change, effects, maximum rainfall, storm water, climate scenarios

1 Introduction

The warming of the earth and its effect on the water cycle is an issue that today all the scientists of the field of science have agreed with the effect. The IPCC reported (with 99% confidence) that the surface temperature will increase between 0.4-0.78°C from the 19th century [1]. Also, in the world scale since the year of 1990, we have been 10 years of severe drought [2, 3].

According to the IPCC, observed heating, over the last few decades, has led to a change in the hydrological cycle and in large scale, cause increasing evaporation, changing rainfall patterns, increasing severe events, reducing snow area and increasing melting levels, changes in soil moisture and runoff [4]. So the probability of encountering major climatic events such as flooding have increased [5, 6]. Since increasing this probability for the future period can have harmful effects on human societies, in recent years, researches on this topic have done for the various catchment areas at the surface of the planet [7–9]. All the researches showed that the effects of climate change on storm water and flood damage may be significant, but this depends on the climate scenarios used [10, 11]. There are some reasons that show global warming can lead to an increase in PMP [12]. First, the Clausius- Clapeyron relationship shows that the water Saturation vapor pressure increases with temperature, so the production system can produce more rainfall. Secondly, heating can cause an increase in the length of the convection season, especially when the maximum precipitation events occurred [13,14]. Another issue is that rising runoff in the rainy season can increase the risk of storm water and flooding [15, 16]. Therefore, maximum flood risk in rivers (PMF) is one of the important criteria for designing hydraulic structures which according to this phenomenon can change [17, 18]. reviewed the flood changes of the present century in Europe and analyzed the peak discharge values using appropriate statistical distributions. The results of this study showed that flood values doubled with return period of more than 400 years over the course of three decades in Europe [19, 20]. Arnell and Gosling [11] investigate the magnitude of the large changes, and the return period of peak flood on a global scale using the HadCM3 model and scenario A1B. According to their results, in 10% of the regions, floods with a return period of 400 years in 2050 at least two times can

happen, and flood risk changes will range from -9% to 378%. Arnell *et al.*, [10] on a research showed that by doubling CO_2, the frequency of heavy rainfall increased and the frequency of low rainfall events decreased. It also showed that the return period for heavy rainfall in Australia declined [21, 22]. showed the changes in the potential damage caused by flood events due to the increase of CO_2 concentration in the three river basins Hawkesbury-Nepean and Quean Beyan and Upper Parramatta in South Australia. In the research, most of the scenarios for GCM models predict little variation in urban flood damage, while with a CO_2 doubling scenario, more damage was estimated. [23, 24] 2020 contributors (1000) examined the effects of a change in urban flood events in watersheds in Wales and the United Kingdom. In this research, the HADCM2 model and the UKCIP98 variation scenario have been used, while the use of this scenario shows a small change in the frequency of heavy floods, but the flood returns vary [25]. Javadinejad *et al*. [26] in a study showed that rainfall intensity for future time period in the Bakhtiari basin willhigher than intensity rainfall for historical time period, which indicates an increase in flood events in the upcoming period. Hemmati and Javadinejad *et al* [27] . with a study of the effect of changes in the flow rate (minimum and maximum flood flow) in the Sefid Rud basin, showed that the total annual precipitation and the maximum precipitation of 11 hours were significant in a small number of stations, while minimum and maximum flood events, this ratio is higher [28]. Arheimer and Javadinejad *et al*. [29] investigated the effect of climate change on variation in flood regime in a basin (on intensity and frequency). The results of probabilistic distribution fitting to the maximum annual flood series and comparing the severity of floods with different return periods with observed data indicate that the impact of climate change can alter the flood regime of the basin in the coming periods. Considering the importance of the Zayandeh Rud Basin as one of the most important watersheds in Iran for the discharge and the existence of hydraulic structures, the construction that plan to build in this basin, so it is important to understand how climate change affects the storm flow and probability of maximum flood and following that how climate change can effect on dimensions of the structures and the necessary planning during storm water and flood events [30, 31]. Therefore, the purpose of this study is to investigate the effect of climate change on the maximum precipitation and maximum flood potential of this river in Ghale-Shahrokh station. For this purpose, maximum potential precipitation (PMP) and maximum potential flood (PMF) were then first determined, and then the effect of the change in the maximum and maximum flood events was studied.

2 Study area

The study basin is one of the main basin districts of the desert, with an area of 41548 square kilometers, between $32°10'$ to $33°40'$ northern latitude and $50°30'$ to $53°23'$ eastern longitude. The geographical area is limited from the north of Salt Lake to the west of the Gulf of Oman and the Oman Sea, and from the east of the Kavir-siyahkooh mountain range to the south of the Kavirirsirjan subzone. Among its important rivers, Zayandeh Rood has a length of 405 K, Khoshkehrood River has a length of 165 km, Izodkhad has a length of 125 km, Segonbad has a length of 85 km, Kahrooye has a length of 60 km long, Dharar has a length of 52 km, Esfarian has a length 50 km, Tighezard has a length of 50 km, and Joshaghan has a length of 40 km. The catchment area covers parts of the provinces of Isfahan, Chaharmahal and Bakhtiari, Fars and Yazd, with Isfahan Province having more than 83% and Yazd having less than 3.5%, the largest and the lowest shares, respectively. Figure 1 shows the study area.

Natural flows of the Zayandehrood River increase with the diversion of water from the deviant tunnels of the first and second Koohrang, which originates from Koohrang River in Chaharmahal and Bakhtiari province. Because the average rainfall in the basin isless than 150 mm per year. Zayandeh Rud Dam storage in Chadegan is provided by spring and winter runoff and released as a stream set in the river. The upstream parts of the basin cover less than 10% of the entire basin, which is mostly mountainous. The central and lower parts of the basin consist of sedimentary plains, with the most consuming agriculture (89%). Also, a large number of overflows and detours have been constructed along the river, thus water is drained for urban and industrial areas. Zayandehrud basin ends in natural swamp and gullous salts. In this research, the meteorological data for determining the future climate of this area and the statistics of hydrometric stations data are used to simulate the runoff used in station selection. Criteria such as the existence of long statistics of low statistical errors are considered.
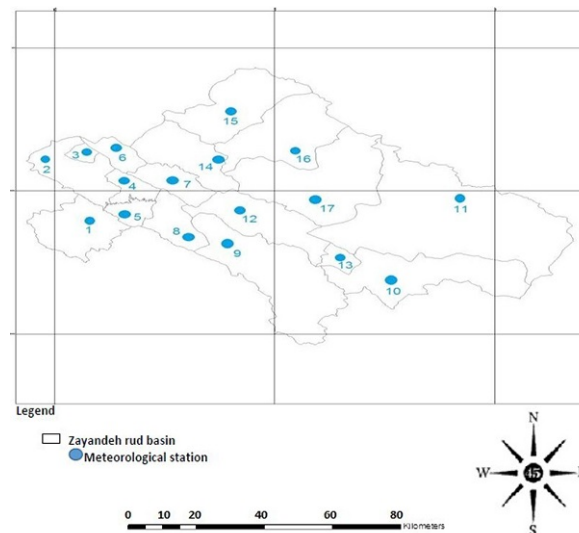
Figure 1   The area studied in the Zayandeh Rood Basin [27]

3   Methods

To do this research, at first, maximum probable rainfall (PMP) was estimated by synoptic method for different continuations. Then, using the HEC-HMS rainfall model and snow melting SRM, the maximum probable flood (PMF) was estimated. In the next step, the parameters of temperature and precipitation parameters of the general circulation model of HadCM3 atmosphere were quantified using the LARS-WG statistical method and the change factor method. By introducing the values of precipitation and temperature (which are downscaled) and applied to the hydrological models used, the impact of variations of precipitation and temperature (as climatic parameters) on the storm water and maximum flood probability was estimated.

3.1   Data

The data required in this study is data on several rain gauge and hydrometric stations and weather data such as minimum temperature, maximum temperature, precipitation, sunny day, wind speed, dew point temperature, and pressure. This information was obtained from the Meteorological Organization and the Ministry of Energy. The Figure 1 and Figure 2 show the position of the rain gauge stations and hydrometers used on the map of the area.

3.2   Estimated maximum probable precipitation

After accurately checking the daily rainfall statistics of basin stations and comparing them with discharge of hydrometric station, seven storms which had maximum rainfall and maximum discharge, were identified and extracted. Then, for the spatial distribution of storm rainfall using Kriging statistical ground method and semi-exponential variogram model, the storm levels were plotted in GIS environment for different continuity and estimated by means of DAD measure method for rainfall storms.

In the next step, after the extraction of the maximum 12-hour dew point in 40-day periods in a long period of time, the frequency analysis was used for this data. Then using the normal log distribution as the most suitable distribution for this quantity, the dew point temperature for the different return periods was extracted using the Hyfa software and based on the recommendations of the World Meteorological Organization, the temperature of the 12-hour steady dew point with a 50-year return period was used to calculate the coefficient Maximization selected. Then, in order to optimize the moisture content, using the Skew-T-Log-P diagram, the maximum temperature of the storm dew point and the maximum dew point temperature with a period of 50 years return to 4000 HPA, and according to the proposed World Meteorological Organization's tables, the precipitable water for each storm Selected and for the studied stations were calculated. To calculate the moisture maximization coefficient, the general relationship of precipitation
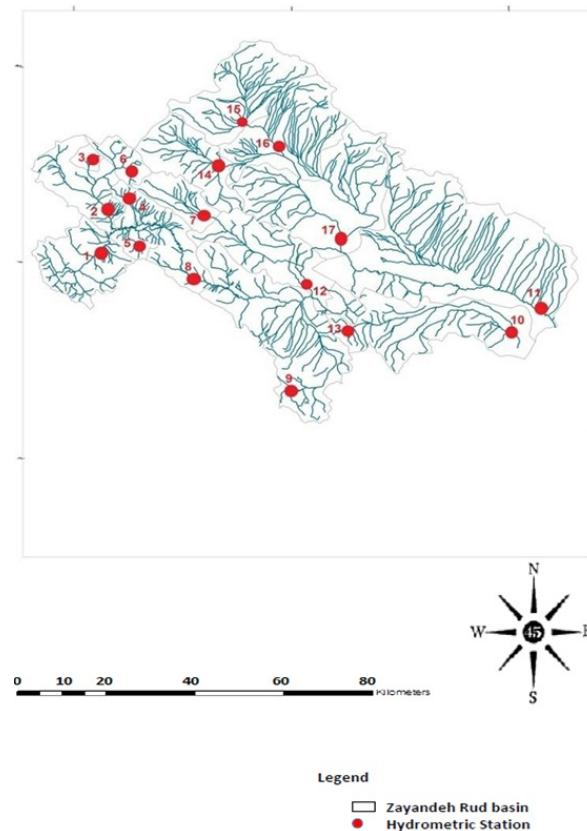
Figure 2   Location of hydrometry station

water content for maximum dew point temperature with continuous 41-hour persistence with a 50-year return period over a ten-day period has been used to provide precipitated water for maximum dew point temperatures with a 41-hour continuation in the storm days. The maximum coefficient of the storm is calculated with respect to climatic elements that maximize the flow of moisture into the storm and maximize rainfall. In fact, the storm maximization coefficient is the maximum potential for precipitation, which is obtained from the following equation.

$$FM = MP \times MW \tag{1}$$

Where, FM is the storm maximization coefficient with a maximum input moisture content, MP is the maximum precipitation factor depending on the temperature of the 41-hour dew point and MW is the maximum wind speed of 41 stable hours.

In the current study, the equal humidity in the source of moisture and the area under study and the high simultaneous effect of both factors of maximization, the wind coefficient in calculations of maximum probable rainfall has not been applied. In fact, with the application of the wind factor in a proportional manner, the maximum probable precipitation is estimated to be much higher than that of the real bearer. Therefore, in the above equation, MW = 1 is assumed, and the final maximization factor is equal to the moisture maximization factor.

3.3   Rainfall distribution pattern

In the process of converting maximum probable rainfall to maximum flood, determining the pattern of rainfall distribution in stations and in the area under study is essential. To do this, firstly, multi-storm rainfall data with different.

3.4   Emission scenarios

The IPCC has so far presented different scenarios, the RCP (Representative Concentration Pathways), is the most recent one. In this research, three RCP 2.6, RCP 4.5 and RCP 8.5 emission scenarios were used to study temperature and precipitation changes. The different scenarios shows the smooth, mild and severe conditions of climate change.

3.5   Creating a changeable scenario

In order to eliminate disturbances in the simulation of climate fluctuations due to the large size of the computational cells of the models AOGCM, as a rule, instead of directly using model data in climate change calculations, the yearly average of this data is used. Therefore, in order to calculate the climate change scenario in each model, the "difference" values for the temperature from equation 2 and "ratio" for the rain, from equation 3 for the long- term average of each month for future time period (2006-2040) and the simulated period (1971-2005) base by the same model calculated for each cell of the computing grid. Time constants were plotted as non-dimensional. To make the non-dimensional, the data of each storm, the cumulative depth of precipitation was divided up into the total depth of the storm. The same method was used for the time axis. Analyzing the stability data of rainfall stations in the basin, it was found that at most stations 40% of precipitation in the first quarter, 90% of precipitation in the second quarter, 10% of rainfall in the third quarter and 10% of precipitation occurred in the fourth quarter time.

$$\Delta = (TGCMfut - TGCMbase) \tag{2}$$

$$\Delta P = \frac{P\ GCM\ FCT}{P\ GCM\ base} \tag{3}$$

3.6   Creating a climate scenario for the future

Most climate predictions are based on the simulation of general atmospheric cycle models. GCM Models in the spatial scale usually brings the atmosphere to 5 to 10 unequal layers, and the layers close to the Earth's surface are less spaced.

In this research, the output of the HadCM3 model from the climate research and forecasting center Hadley in England is used. Because this model has the best similarity with observed data in CDF curve and among 39 models the model of HadCM3 is used, because it shows better climate signal when compare simulated and observed model of historical period.

In equation 2, T GCM fut is the 34 year average temperature simulated by AOGCM for future time period. T GCM base is the34 year average temperature simulated by the AOGCM - in the same period as the observed time period. Equation 2 is for the precipitation.

3.7   Spatial downscaling

One of the major problems in using the output of AOGCM models is the large scale of their computing cells in terms of the spatial changes of study area in the region. In this study, to downscale the data are based on the LARS-WG statistical model.

The LARS-WG model is an artificial data source for weather data that can be used to simulate meteorological data in a single location of current and future climate conditions. The statistical properties of the generated data (modeled data) are similar to the statistical properties of historical period (observed data) but the standard deviations of GCM model are different from observed data. Data is generated in daily time series for a series of suitable climate variables such as rainfall, minimum and maximum temperature, and radiation. After assuring the accuracy of the results of the model's assessment and its ability to simulate the meteorological data, this model was used for quantifying the data of the HadCM3 atmospheric general circulation model and producing or simulating the climatic data of 2006-2040 using RCP 2.6, RCP 4.5 and RCP 8.5 scenarios and the daily values of climate parameters were generated.

3.7.1   Temporal downscaling

n this research, the change factor method is used to minimize the scale of the project data. In this method, relations 4 and 5 are used to obtain the time series of the future climate scenario.

$$T = Tobs + \Delta T \tag{4}$$

$$P = Pobs * \Delta P \tag{5}$$

In the above equation, T obs represents the time series of the monthly observational temperature in the base period (1971-2005), and T is the time series of temperature from climate change for the future period (2006-2040) and Δ T is the downscaled scenario. In the equation 5, all above relationship is for rainfall.

3.7.2 Rainfall Run-Off model

In the present study, HEC-HMS model was used to convert rainfall into runoff. From the critical storms, several storms were selected to calibrate the model in terms of the quantity and quality of basic data.

For example, in Figure 3 and Figure 4, observing and calculating hydrographs of the storm of March 1 in the year of 2006 hurricane, are shown in the Ghale-Shahrokh mapping hydrometric station for calibrating and validating the model. So, Figure 3 shows that there is a delay between observed and modeled data. The comparison between hydrographs shows that there is a good fit between computational and observational hydrographs.
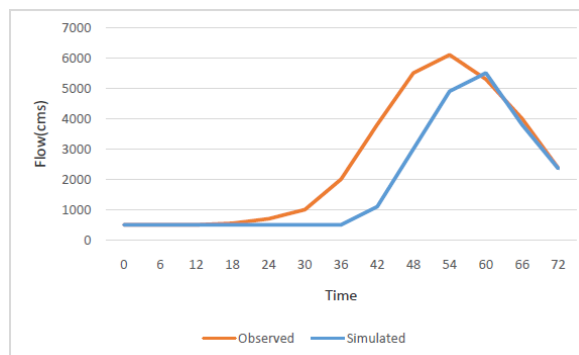
Figure 3   Observational and calculated hurricane hydrograph in 1th March 2006
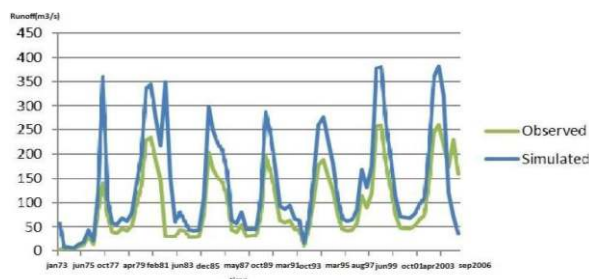
Figure 4   Calibration of SRM (1971-2005)

3.8 Snow melting

In this study, a snow flake with a 100-year return period was used to estimate the contribution of snow melt to storm water and the maximum probable maximum flood. For this purpose, snow melting was used and the Meteorological Station of Ghale-Shahrokh was selected as the base meteorological station and the Ghale-Shahrokh hydrometric station as the base of the hydrometric station.

Hydrology years of 1971-2005 were selected for calibration and evaluation, respectively, due to more complete snow cover data.

The determination coefficient for the calibration period is about 0.8, and the volume difference percentage for the aforementioned periods is 0.77, which indicates the proper performance of the model. Figure 4 shows the observed and simulated snowmelt hydrographs for calibration period.

4   Results

As mentioned above, in this research, maximum probable precipitation is estimated by synoptic method. Due to temperature changes and its future period, the maximum probable precipitation for the future period is predicted for different continuations under scenarios RCP 2.6, RCP 4.5 and RCP 8.5. Table 1 shows the maximum probable rainfall of the basin in the current and future periods under changing conditions and different scenarios.

Table 1   Maximum probable precipitation depth at basin level

Scenario	PMP 24 hours	PMP 48 hours	PMP 72 hours
Present	128	171	186
RCP 2.6	141	188	205
RCP 4.5	134	181	195
RCP 8.5	122	163	177

After calibrating the HEC-HMS model, using this model, the runoff was simulated with a maximum probable 24-hour, 48-hour and 72-hour rainfall. Table 2 shows the comparison of rainfall runoff from the maximum 24 hours, 48 hours and 72 hours for the current period and the upcoming period under changing conditions, as well as Table 3 shows the comparing variations in runoff volume for the periods.

Table 2   Comparison of the percentage of runoff variations caused by precipitation of the maximum future period with the current period under climate change

Scenario	The percentage of runoff changes due to the 24-hour precipitation	The percentage of runoff changes due to the 48-hour precipitation	The percentage of runoff changes due to the 72-hour precipitation
RCP 2.6	+20%	+16%	+15%
RCP 4.5	-16%	+7%	+6%
RCP 8.5	-17%	-11%	-10%

Table 3   Comparison of the percentage changes in the runoff volume due to the maximum rainfall of the future period with the current period under the climate change

Scenario	The percentage of runoff volume changes due to the 24-hour precipitation	The percentage of runoff volume changes due to the 48-hour precipitation	The percentage of runoff volume changes due to the 72-hour precipitation
RCP 2.6	+18%	+20%	+17%
RCP 4.5	-14%	+9%	+8%
RCP 8.5	-15%	-11.5%	-10%

In the next stage, after calibration of the SRM snow melting model, snowmelt runoff using this model was simulated in the current and future period under the three climate scenarios, and the flood with a 100-year return period with Two-parameter gamma distribution and torque method were calculated. Table 4 shows Flood amounts due to snow melting with a return period of 100 years in the present and future periods under conditions of climate change. Finally, by adding the melting point to the runoff caused by maximum precipitation, the maximum probable flood of the basin was obtained in continues and different periods.

Table 5 shows the maximum variation of the probable river flood under scenarios different in comparison with the base course.

5   Discussion

Previous studies such as Javadinejad *et al*. [32] and Harris [33] and Beery [34] mentioned that still there is gap between selecting climate change model and modeling storm water.

So, this study tried to fill the gap with using new method for selecting the model of climate change and analyze the effects of climate change on hydrological system of a catchment.

So, this study tried to fill the gap with using new method for selecting the model of climate change and analyze the effects of climate change on hydrological system of a catchment.

Also, previous studies such as Javadinejad *et al*. [35] and Douglas *et al*. [36] did not analyze the effect of climate change on seasonal storm water. However, this study analyze the effects of climate change on hydrological seasons. In addition, previous studies such as Li N *et al*. 2018 and Javadinejad *et al*. [16] did not analyze the effect of snow melt in storm water simulation under the climate change effects. However, these studies analyze the effect of snow melt in hydrology system of catchment and assess the effect of climate change on snow melt and storm water Javadinejad *et al*. [37] and Javadinejad *et al*. [38] and Javadinejad *et al*. [39] and Javadinejad *et al*. [40] and Dara *et al*. [41].

In this research, the effects of climate change on storm water and probability for maximum flood during the period 2006-2040 analyzed with using HadCM3, under the three scenarios

Table 4   The flood variation ratio with a return period of 100 years due to snow melt in the course of the current period under the climate change conditions

Scenario	Variation ratio
RCP 2.6	1.24
RCP 4.5	1.25
RCP 8.5	1.59

Table 5   Comparison of the maximum flood variations in the future period compared to the current period under different scenarios

Scenario	The change in probable maximum flood for 24 hour	The change in probable maximum flood for 48 hour	The change in probable maximum flood for 72 hour
RCP 2.6	+25.5%	+19%	+18%
RCP 4.5	+24%	+11%	+10%
RCP 8.5	-9%	-7.3%	-7.2%

climate change model showed that under the RCP 2.6 scenario, there is increase in temperature (0.35 °C) and under the RCP 4.5 scenario, there is increase in temperature (0.48 °C) and under the RCP 8.5 scenario, there is increase in temperature (0.53 °C). The warmer months of the year, warmer and cold months of the year, will experience changes that in general will change by 3% increase in the future temperature. Anomalies in temperature variations, even minor changes, will be the beginning of a change in the trend of many hydrological phenomena in the region. The trend of rainfall changes in the future will have a different behavior over the historical period. At the same time period, in some months of the year rainfall is decreasing and in some months rainfall is increasing. According to rainfall forecast, under the scenario 1, maximum probable of precipitation is increased by 5% and under the scenario 2 the maximum probable of precipitation is decreased by 5% and under the scenario 3 the maximum probable of precipitation is decreased by 10%.

To simulate the rainfall-Runoff a hydrological model was used. According to rainfall-runoff forecast, under the scenario 1, maximum storm water is decreased by 1.23% and under the scenario 2 the maximum storm water is decreased by 1.25% and under the scenario 3 the maximum storm water is decreased by 1.53%.

This increase over the course of the year is not the same and varies in different months. The existence of a difference in the predicted values of the climate change scenario for temperature and fluidity in different months during the evaluation period indicates that the uncertainty in the simulation under the phenomenon of climate change.

Anyway in the appearance of such changes in temperature and precipitation, intensity and the duration of droughts will increase due to increased temperature and also the risk of flooding due to melting snow and increasing the Evapotranspiration of plants from other disruptions to change the climate is in the region. Finally, it can be concluded that such studies and studies of future climate changes in the different regions or countries and simulation of rainfall-runoff and prediction of future runoff of rivers, can help to improve the possibility of making decisions management, modifying the probabilistic effects and applying new methods of adaptation to different climatic conditions and using the results of climatic research in areas where rainfall and runoff are increasing can help to predict the risk of flooding by hydrological models in those areas.

6   Conclusion

The result of this study showed that the variation in the studied basin would dramatically change precipitation, melting, and flooding. As shown in the results section, the maximum probable rainfall in the catchment area has occurred with different continents in December. During the period of 2006-2040 this month, under the scenario1, the precipitation can increase by 5 percentage, under the scenario 2, can decrease by 5%, and under the scenario 3 can decrease by 10%.

Accordingly, maximum flood variations for the upcoming period under the A1B, A2, and B1 scenarios for precipitation of 24 hours duration were 25.5, 24 and 9% respectively, and for precipitation with a duration of 48 hours, 19, 11 and 7.3%, and For precipitation with a duration of 72 hours, 18, 10 and 7.2%, this change can affect the structures that are designed based on

the maximum flood event or the structures that are being run along the river.

Of course, it should be noted that due to the existence of different models of AOGCM, down scaling, different greenhouse gas emission scenarios, there is uncertainty in the final results of this research. It should also be noted that how simulation of runoff and snow melt modeling and calibration of models can affect the final results of maximum flood probability.

However, with the change in the severity of heavy rainfall and storms, it is recommended that water resource managers approach to water management practices that reduce the impact of severe storms and increase flexibility in water management. In addition, as suggestions for future studies, it is recommended to use evolutionary methods for optimization to calibrate the runoff rainfall model. Also, use of other models of runoff precipitation, other models-AOGCM and other scenarios for publication and comparison with the results of this study are recommended for future research.

7 Data availability

Some or all data, models, or code used during the study were provided by a third party. Direct requests for these materials may be made to the provider as indicated in the Acknowledgements. The data include:

Minimum temperature, maximum temperature, precipitation, sunny day, wind speed, dew point temperature, and pressure was obtained from the Esfahan Regional Water Authority, Meteorological Organization and the Ministry of Energy.

Acknowledgements and funding

References

[1] Javadinejad S, Ostad-Ali-Askari K and Jafary F. Using simulation model to determine the regulation and to optimize the quantity of chlorine injection in water distribution networks. Modeling Earth Systems and Environment, 2019, **5**(3): 1015-1023.
https://doi.org/10.1007/s40808-019-00587-x

[2] Javadinejad S, Eslamian S and Ostad-Ali-Askari. The Analysis of the Most Important Climatic Parameters Affecting Performance of Crop Variability in a Changing Climate. International journal of hydrology science and technology, 2018.

[3] Javadinejad S, Dara R and Jafary F. Evaluation of hydro-meteorological drought indices for characterizing historical and future droughts and their impact on groundwater. Resources Environment and Information Engineering, 2020, **2**(1): 71-83.
https://doi.org/10.25082/REIE.2020.01.003

[4] Javadinejad S. The 2008 Morpeth Flood: Continuous Simulation Model for the Wansbeck Catchment. Ebook, Grin publication. 2011.

[5] Javadinejad S, Dara R and Jafary F. Analysis and prioritization the effective factors on increasing farmers resilience under climate change and drought. Agricultural research, 2020, 1-17.
https://doi.org/10.1007/s40003-020-00516-w

[6] Mirramazani SM, Javadinejad S, Eslamian S, *et al*. The origin of river sediments, the associated dust and climate change, 2019, **8**(2): 149-172.

[7] Kundzewicz ZW, Su B, Wang Y, *et al*. Flood risk in a range of spatial perspectives–from global to local scales. Natural Hazards and Earth System Sciences, 2019, **19**(7): 1319-1328.

[8] Javadinejad S, Dara R and Jafary F. Taking Urgent Actions to Combat Climate Change Impacts. Annals of Geographical Studies, 2019, **2**(4): 1-13.

[9] Javadinejad S, Eslamian S, Ostad-Ali-Askari K, *et al*. Embankments. In: Bobrowsky P., Marker B. (eds) Encyclopedia of Engineering Geology. Encyclopedia of Earth Sciences Series. Springer, Cham. 2018.
https://doi.org/10.1007/978-3-319-12127-7_105-1

[10] Arnell NW, Brown S, Gosling SN, *et al*. Global-scale climate impact functions: the relationship between climate forcing and impact. Climatic Change, 2016, **134**(3): 475-487.
https://doi.org/10.1007/s10584-013-1034-7

[11] Arnell NW and Gosling SN. The impacts of climate change on river flood risk at the global scale. Climatic Change, 2016, **134**(3): 387-401.
https://doi.org/10.1007/s10584-014-1084-5

[12] Chen X and Hossain F. Understanding future safety of dams in a changing climate. Bulletin of the American Meteorological Society, 2019, **100**(8): 1395-404.
https://agupubs.Onlinelibrary.wiley.com/doi/abs/10.1002/2017WR021094

[13] Javadinejad S, Eslamian S and Ostad-Ali-Askari K. Investigation of monthly and seasonal changes of methane gas with respect to climate change using satellite data. Applied Water Science, 2019, **9**(8): 180.
https://doi.org/10.1007/s13201-019-1067-9

[14] Javadinejad S, Ostad-Ali-Askari K and Eslamian S. Application of Multi-Index Decision Analysis to Management Scenarios Considering Climate Change Prediction in the Zayandeh Rud River Basin. Water Conservation Science and Engineering, 2019, **4**(1): 53-70.
https://doi.org/10.1007/s41101-019-00068-3

[15] Javadinejad S, Dara R and Jafary F. Gray Water Measurement and Feasibility of Retrieval Using Innovative Technology and Application in Water Resources Management in Isfahan-Iran. Journal of Geographical Research, 2020, **3**(2).
https://doi.org/10.30564/jgr.v3i2.1997

[16] Mirramazani SM, Javadinejad S, Eslamian S, *et al*. A Feasibility Study of Urban Green Space Design in the Form of Smart Arid Landscaping with Rainwater Harvesting, American Journal of Engineering and Applied Sciences, 2019.
https://doi.org/0.3844/ajeassp.201.1-9

[17] Javadinejad S, Dara R, Hamed MH, *et al*. Analysis of Gray Water Recycling by Reuse of Industrial Waste Water for Agricultural and Irrigation Purposes. Journal of Geographical Research, 2020, **3**(2).
https://doi.org/10.30564/jgr.v3i2.2056

[18] Javadinejad S, Dara R and Jafary F. Analysis and prioritization the effective factors on increasing farmers resilience under climate change and drought, Agricultural research, 2020.
https://doi.org/10.1007/s40003-020-00516-w

[19] Gobiet A, Kotlarski S, Beniston M, *et al*. 21st century climate change in the European Alps-a review. Science of the Total Environment, 2014, **493**: 1138-1151.
https://doi.org/10.1016/j.scitotenv.2013.07.050

[20] Javadinejad S, Dara R, Jafary F, *et al*. Climate change management strategies to handle and cope with extreme weather and climate events. Journal of Geographical Research, 2020, **3**(4).
http://dx.doi.org/10.30564/jgr.v3i4.2324

[21] Javadinejad S, Dara R and Jafary F. Potential impact of climate change on temperature and humidity related human health effects during extreme condition. Safety in Extreme Environments, 2020, **2**(2): 189-195.
https://doi.org/10.1007/s42797-020-00021-x

[22] Javadinejad S, Dara R and Jafary F. Modelling groundwater level fluctuation in an Indian coastal aquifer. Water SA, 2020, **46**(4): 665-671.
https://doi.org/10.17159/wsa/2020.v46.i4.9081

[23] Dadson SJ, Hall JW, Murgatroyd A, *et al*. A restatement of the natural science evidence concerning catchment-based natural'flood management in the UK. Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences, 2017, **473**(2199).
https://doi.org/10.1098/rspa.2016.0706

[24] Javadinejad S, Dara R and Jafary F. Investigation of the effect of climate change on heat waves. Resources Environment and Information Engineering, 2020, **2**(1): 54-60.
http://dx.doi.org/10.25082/reie.2020.01.001

[25] Javadinejad S, Dara R and Jafary F. Effect of Precipitation Characteristics on Spatial and Temporal Varia-tions of Landslide in Kermanshah Province in Iran. Journal of Geographical Research, 2019, **2**(4).
https://doi.org/10.30564/jgr.v2i4.1818

[26] Javadinejad S, Dara R and Jafary F. Climate Change Scenarios and Effects on Snow-Melt Runoff. Civil Engineering Journal, 2020, **6**(9): 1715-1725
https://doi.org/10.28991/cej-2020-03091577

[27] Javadinejad S. Vulnerability of water resources to climate change and human impact: scenario analysis of the Zayandeh Rud river basin in Iran (Doctoral dissertation, University of Birmingham), 2016.

[28] Arabzadeh R, Kholoosi MM and Bazrafshan J. Regional hydrological drought monitoring using principal components analysis. Journal of Irrigation and Drainage Engineering, 2016, **142**(1).
https://doi.org/10.1061/(ASCE)IR.1943

[29] Javadinejad S, Eslamian S, Ostad-Ali-Askari, K, *et al*. Relationship Between Climate Change, Natural Disaster, and Resilience in Rural and Urban Societies, 2019.
https://doi.org/10.1007/978-3-319-93336-8_189

[30] Javadinejad S, Dara R and Jafary F. Impacts of Extreme Events on Water Availability. Annals of Geographical Studies, 2019, **2**(3): 16-24.

[31] Javadinejad S, Dara R and Jafary F. Examining the association between dust and sediment and evaluating the impact of climate change on dust and providing adaptation. Resources Environment and Information Engineering, 2020, **2**(1): 61-70.
http://dx.doi.org/10.25082/reie.2020.01.002

[32] Javadinejad S, Ostad-Ali-Askari K, Singh VP, *et al*. Reliable, Resilient, and Sustainable Water Management in Different Water Use Sectors. Water Conservation Science and Engineering, 2019, **4**(2-3): 133-148.
https://doi.org/10.1007/s41101-019-00073-6

[33] Harris CR. Green Infrastructure for Chesapeake Stormwater Management in a Changing Climate. Envtl. L. Rep. News & Analysis, 2018, **48**: 10150.

[34] Beery T. Engaging the private homeowner (2018) Linking climate change and green stormwater infrastructure. Sustainability, **10**(12): 4791.
https://doi.org/10.3390/su10124791

[35] Javadinejad S, Hannah D, Ostad-Ali-Askari K, *et al*. The impact of future climate change and human activities on hydro-climatological drought, analysis and projections: using CMIP5 climate model simulations. Water Conservation Science and Engineering, 2019, **4**(2-3): 71-88.
https://doi.org/10.1007/s41101-019-00069-2

[36] Douglas EM, Kirshen PH, Bosma K, *et al*. Simulating the impacts and assessing the vulnerability of the central artery/tunnel system to sea level rise and increased coastal flooding. Journal of Extreme Events, 2016, **3**(4):1650013.
https://doi.org/10.1142/S2345737616500135

[37] Javadinejad S, Dara R and Jafary F. How groundwater level can predict under the effect of climate change by using artificial neural networks of NARX. Resources Environment and Information Engineering, 2020, **2**(1): 90-99.
https://doi.org/10.25082/REIE.2020.01.005

[38] Javadinejad S, Hannah DH, Krause SK, *et al*. The impacts of climate change on energy-water systems and economic analysis. The Iraqi Geological Journal, 2020, 1-17.
https://doi.org/10.46717/igj.53.2F.1Ms-2020-12-24

[39] Javadinejad S, Hannah D, Krause S, *et al*. Building socio-hydrological resilience "improving capacity for building a socio hydrological system resilience". Safety in Extreme Environments, 2021, 1-14.

[40] Javadinejad S, Dara R, Jafary F, *et al*. A Review on Homogeneity across Hydrological Regions. Biogeneric Science and Research, 2021, 30, **7**(4).
https://biogenericpublishers.com/pdf/JBGSR.MS.ID.00173.pdf

[41] Dara R, Jirjees S, Fatah KK, *et al*. Climatic Parameters Analysis of Koysinjaq Meteorological Station, Kurdistan Region, Northern Iraq. Iraqi Geological Journal, 2021, **54**(1A): 99-109.
https://doi.org/10.46717/igj.54.1A.9Ms-2021-01-30