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A Study of Rainfall and Urban Runoff Flow Regime under Future Climate Condition (Case study: West Flood-Diversion Catchment in Tehran)

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ABSTRACT: Among the climate change impacts, changing hydrologic regime and increasing the probability of encountering extreme events are of the most important. This paper investigates extreme rainfall and runoff regime (intensity and frequency) under climate change impact in West Flood-Diversion (WFD) catchment in Tehran, and compares the changes in extreme rainfall and runoff return periods during future time period (2080-2090) with baseline period (1999-2000). To do this, the output of MRI-CGCM2.3.2a climate model under A1B emission scenario was extracted as a point (station scale) and change factor method was used for downscaling and producing daily rainfall time series. Afterwards by extracting extreme daily rainfall data, the value of 1-hour, 10-year rainfall of the catchment was calculated and then IDF curves of the catchment for base time period and also the future period were obtained. Finally by extracting PDFs of Maximum runoff, changes in catchment's runoff regime in future period compared to baseline period were analyzed. The results showed that extreme rainfall intensity at future decreases a little compared to base time period. In addition the results are representative of enhancing catchment's runoff discharges in 2090 time horizon compared to baseline period. By moving from baseline to the future, the catchment faces increasing in frequency and probability of a given amount of runoff discharge occurrence, and also for a given return period, urban flood flow-rate increases. Therefore employing measures for adaptation to climate change impacts in the catchment seems to be necessary.

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1- Introduction

Available documents show that global hydrologic cycle has reacted to global warming- and consequently, changing precipitation patterns- in recent decades [1]. According to the Intergovernmental Panel of Climate hange (IPCC) [2], the climate change impact on hydrologic regime has caused increase in extreme events' occurrence such as flooding. Floods are of the most important natural disasters which can result in significant loss of lives and properties. Influencing the flood frequency and magnitude in local and regional hydrological systems, climate change has a significant impact on mid-term to long-term planning of flood damage prevention. This study investigates the effect of climate change on change in catchment's extreme runoff regime in 2090 time horizon in an urban basin (which is less discussed in the previous studies).

2- Methodology

Methodology of current research includes two parts: future rainfall simulation and rainfall-runoff modelling. Then the methodology was applied on West Flood-Diversion (WFD) catchment in northern part of Tehran, Iran. First, required data for both simulation processes were gathered and arranged through different sources. Precipitation data for the studied time periods were extracted as point (station) scale from "Canadian Climate Data and Scenarios" website, and their long-term average was calculated for each month. The only available station inside WFD basin is Haft-Howz station in Darakeh sub-basin which is actually a hydrometer station, however, it includes rainfall data for a couple of years (1989-2012). According to IPCC recommendation on choosing baseline period as: 1961-1990 or 1971-2000 in climate studies, eventually an 11-year period (1990-2000) was considered as the base period in current research. Future rainfall was also investigated during an 11-year period (2080-2090).

Atmosphere-Ocean Global Circulation Models (AOGCMs) are of the most reliable tools for generating future climate projections [3-6] whose the most important input is future emission scenarios [7]. In current study, climate simulations was done using A1B emission scenario. This scenario is from A1 family which its emphasis is on quick economic growth and balanced use of different energy sources. In addition, population growth by 2050 and developing new and efficient technologies are of other characteristics of A1 scenario family. Downscaling was done through Delta Change Factor method.

In the next stage, Intensity-Duration-Frequency (IDF) curves were obtained using relations offered for Iran conditions by Ghahreman [8] and Ghahreman and Sepaskhah [9] for

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estimating 15-min to 20-hr rainfall and 2-year to 100-year return period. The relations are based on equation proposed by Ball [10].

Rainfall-runoff simulation was conducted using Storm Water Management Model (SWMM 5.0), which is a suitable software for modelling runoff quantity and quality in urban areas. Considering available information of curve number for each single sub-basin, CN method was used to simulate infiltration process in the watershed. Dynamic wave was chosen as flow routing method which accounts for channel storage, backwater, flow reversal, and entrance/exit losses [11, 12]. For required runoff data at the outlet of the catchment, gathered data by Moafi Rabari [13] related to two storms in January 2011 were used. Other information for rainfall-runoff modeling were extracted from model guidelines, available reports, similar previous researches, and studies performed by different engineering companies on the catchment.

After simulating future runoff and generating daily output runoff time series, values of annual extreme runoff are determined using Annual Maximum (AM) method. In the next step, probability and return period of annual extreme discharges were calculated using Weibull formula and Probability Distribution Function (PDF) was obtained. For the baseline period the same process was followed using simulated runoff data by SWMM. Finally, PDFs of baseline and future annual extreme runoff were compared to each other in order to evaluate probable changes in extreme runoff regime of WFD catchment.

3- Results and Discussion

Evaluating different AOGCMs indicated that two models: MRI-CGCM2.3.2.a and IPSLCM4 show the most accuracy in simulating catchment's rainfall, respectively. Based on simulation results from MRI-CGCM2.3.2.a, the amount of future rainfall decreases compared to the base period; while IPSLCM4 projections estimates future precipitation more than baseline. However, MRI-CGCM2.3.2a was used as the climate model for the current research since it provides less errors than IPSLCM4.

IDF curves were obtained for both baseline and future time period, and it turned out that future rainfall intensity decreases for a specific return period. However, future rainfall intensity still increases in general since rainfall return periods increase in the future dramatically.

After calibration and validation of rainfall-runoff model and simulating future runoff in the basin outlet, it turned out that in most times of the year, particularly from late autumn to early spring, the amount of rainfall increases in 2090 time horizon compared to the baseline period. The results showed that annual extreme runoff time series in the studied catchment has a Log-normal distribution for both baseline and future time periods. Figure 1 represents the changes of maximum flow rates at the outlet of WFD catchment for the baseline and future period against return periods for the extreme discharges. It can be seen from the figure that for a given discharge value, flood return period in 2090 time horizon decreases compared to the base period, and for a specific return period, urban flooding flow rate increases significantly in comparison with the baseline.

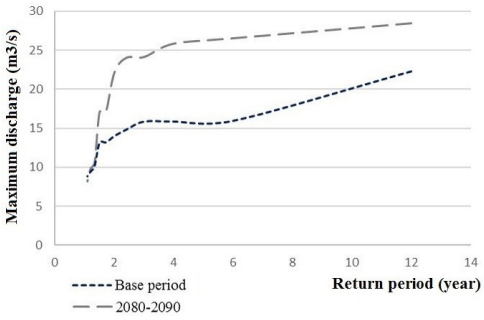

Figure 1. Extreme runoff changes against return period for future and base time periods

4- Conclusions

This paper investigated rainfall and runoff regime in the future time period (2090 time horizon) in comparison with a baseline period (1990-2000). The results showed that the rainfall amount and intensity (for a specific return period) in the catchment will decrease in the future. However, increase in rainfall return period in the future still causes more-intense precipitation. Examining different climate models' projections was representative of significant difference in the results which indicates high level of uncertainty. Therefore future studies are recommended to study such uncertainties.

Simulation of extreme runoff of the catchment showed that the amount and flow rate of extreme runoff in the catchment increases in the future, and also the probability of flood occurrence enhances dramatically, which matches with previous studies in adjacent basins [14, 15]. Therefore employing measures for adaptation to climate change impacts in the catchment seems to be necessary.

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