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Long Term Impact of Climate Change on Precipitation of Greater Zab River Basin, Iraq

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Abstract. Greenhouse gases (GHG) represent two atmosphere gaseous components, natural and made via human activities which cause the global warming phenomena. Climate change and global warming are imposing additional pressures, with negative effects on the quantity and quality of water resources and the capability to ensure food security, protect human health and preserve ecosystems. The present study focuses on responses the characteristics of precipitation due to climate changes over the greater zab river (GZR) basin at Eski-Kalak gauging station (20435 km^2) during the observed period (1979-2005), near (2047-2073) and distant (2074-2100) future periods under both emission scenarios the medium (RCP4.5) and the high (RCP8.5). The regional climate model RCA4 by using Coordinated Regional Climate Downscaling Experiment (CORDEX) program has been utilized to obtain the predictions of precipitation within Middle East North Africa (MENA) region. The results indicated that an increasing in rainy days and intensity of daily precipitation for prediction periods compared to the observed period. Daily analysis over the projection periods indicate that likely to be occurred extreme precipitation on the basin reach to 120 and 132 mm under medium and high emission scenarios, respectively whereas, during the observed period the maximum daily precipitation was 73 mm. The increasing of average annually of total precipitation as a ratio to the observed period were 23% and 28% under scenario RCP4.5 whereas, under high scenario RCP8.5 were 25% and 23% for mid and end 21st century periods, respectively. According to a higher frequency and intensity of precipitation, the GZR basin would be experienced flood events in future.

Keywords: greater zab basin, global warming, precipitation, bias correction, emission scenarios.

1. INTRODUCTION

Climate change is a global common problem and has negative impacts on different sectors of life including water resources. The greenhouse gases resulting from anthropogenic emissions lead to the global warming are the large in date, thus social and natural regimes will be affected with the climate changes [1]. Hydrologic system considered as integral portion of the climate regime. Therefore, the adverse impacts of climate change on water resources is mainly on the hydrological cycle by alter the evapotranspiration and precipitation [2]. Iraq confronts the climate change in all aspects of life particularly water sector [3]. The greater area of Iraq’s land depends on the Tigris River and its tributaries for its living. The Greater Zab River (GZR) is largest Tigris tributary of water yield, its headwaters from Ararat Mountains of south-eastern Turkey then passes through the north of Iraq [4]. Risky weather events like floods and droughts and variability in river discharge probably occur caused by climate change. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation report [5] mentioned that it was very possible that occur heavy precipitation events and its frequency would increase over most regions of the globe in the current century. Many areas which have an increase trend of heavy daily precipitation events, total forecast precipitation was to decrease in some of these areas. Arab climate change assessment report [6] indicated to Precipitation is very considerably variable in the Arab region. In most Arab area, the precipitation trends showed decreasing during two periods (2046-2065) and (2081-2100) with Representative Concentration Pathway emissions scenarios, RCP4.5 and RCP8.5. Nahlah et al. [2] Applied the Soil and Water Assessment Tool (SWAT) model and six climate model from General Circulation Model (GCM) under three emission scenarios: low emissions scenario (B1), scenario (A2) very high emissions and (A1B) medium emissions scenario. To assess the impact of climate change on Lesser Zab basin, northern Iraq for two period (2046-2064) and (2080-2100). Results showed that mean annual precipitation would be reduced, except emission scenario B1 indicated rise precipitation. Filippo Giorgi et al. [7] presented the study of precipitation response to global warming by analyzing the predictions of global climate model as part of the CMIP5 program and regional climate model from CORDEX during the current century. They concluded a decrease in the frequency of wet days but increase of dry days and a rise in the average intensity of precipitation events. Nahlah et al. [8] Studied exposure Isaac River basin in Australia to variability in precipitation caused by climate change. Using six climate model from General Circulation Model (GCM) under emission scenarios: A1B, A2 and B1 for (2046-2064) and (2080-2100) periods. Researchers expected the precipitation will be increased at all scenarios except scenario A2 indicated decrease during near future period. The Present study targets to analyses projections of precipitation by employing regional climate model (RCA4) from Coordinated Regional Climate Downscaling Experiment (CORDEX) under scenarios of emission greenhouse RCP 4.5 and RCP 8.5. The Middle East and North Africa (MENA) region adopted to acquire forecasted long term daily precipitation over GZR basin at mid-21st century (2047-2073) and end-21st century (2074-2100) periods. The daily precipitation for the observed period (1979-2005) were obtained from Water and Global Change (WATCH). The daily, monthly and seasonally analysis were utilized to future assess of precipitation over study basin, which would assistance decision makers to take procedures to overcome, mitigate and adaptation of water scarcity within the basin.

2.Study Area Description

The Grater Zab River (GZR) is the largest Tigris tributary regarding of water income. The basin area of GZR is shared between two countries, 65% from it is located in Iraq and 35% in Turkey. Its main source in the Ararat Mountains of south-eastern Turkey then passes through the north of Iraq [4]. Study area is located geographically in the east Mediterranean zone, bound by Iran in the east and Syria in the west figure (1). GZR Basin at Eski-Kalak gauging station is covered area 20435 km^2, bounded by latitude 36º 5′- 38º 17′ N, and longitude 43º 7′- 44º 53′ E. The Basin is distinguished with high mountainous, terrain surface generally increases in elevation from 240 m to 4000 m a.s.l. towards north and northeast [9]. The maximum stream length of GZR basin is about 462 km, the mean elevation is 1653 meter above m.s.l. and the basin slope is 0.355. These geomorphology parameters are extracted from Digital Elevation Model (DEM) [10]. Snow dominate the basin, snow melting considers the major resource of stream flow. In winter and spring, most of precipitation occurs in the study area with mean annual from 350 to 1000 mm approximately distributed during the year: 48.9%, 37.5%, 12.9% and 0.57% in winter, spring, autumn and summer respectively [11].

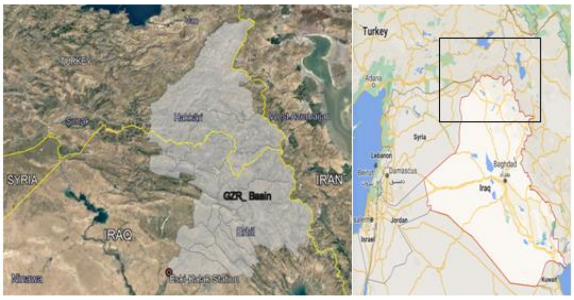

Fig 1. The Location of Greater Zab River Basin

3.Methodology

3.1 Data Preparation

In present study, daily precipitation (rainfall and snow) data was analyzed. The observed data have been obtained from (WFDEI) is WATCH Forcing Data methodology applied to ERA-Interim data and exist in Water and Global Change (WATCH) website for period (1979-2005) [12]. All WFDEI data files contain grid-cell center longitude and latitude with 0.5º x 0.5º resolution and distributed over entire study area. WFDEI has been conducted bias correction for precipitation data with the Global Precipitation Climatology Centre (GPCC). Network Common Data Format (NetCDF) is type of all WFDEI files, therefore, Grid Analysis and Display System (GrADS) software [13] employed to convert data files to excel format. The projections of daily precipitation over GZR basin under impact of global climate change were gained by utilizing Regional Climate Downscaling (RCD) techniques. Coordinated Regional Climate Downscaling Experiment (CORDEX) employed for this aim, with two emissions scenarios and concentrations of greenhouse gases (RCP 4.5) and (RCP 8.5).

3.2 Regional Climate Model

The World Climate Research Programme (WCRP) is organization, aims to analysis, simulate and future predicts of global system climate change, additionally study of population activities impact on future climate system. WCRP instituted at 1980 and existing in Geneva, Switzerland [14] . Coordinated Regional Climate Downscaling Experiment (CORDEX) is programme under WCRP. CORDEX provides climate information for high-resolution at each grid cell with scale 0.44° x 0.44° approximate 50 x 50 kilometers. The statistical downscaling uses empirical relations between large-scale characteristics and local cases assuming that these relationships remain the same in an altering climate. The dynamical downscaling makes use of Regional Climate Models (RCMs) that are set up on a smaller-scale at higher resolution compared to the General Circulation Models (GCMs). CORDEX is utilized both Regional Climate Models (RCMs) and Empirical Statistical Downscaling (ESD) to downscaled local climate data over a domain and driven from a set of General Circulation Models through the multi-model is Coupled Model Intercomparison Project Phase 5 (CMIP5) [15]. To download CORDEX climate data (forecast and historical periods) from Earth System Grid Federation (ESGF) for Greater Zab River basin were utilized Li.U NSC-SMHI is one of ESGF-CoG data nodes [16]. Middle East North Africa (MENA) is one of CORDEX domains was selected because the study area located within it and the Mediterranean cyclones effect it, figure (2). Download daily precipitation (pr), with two experiments of Representative Concentration Pathways to represent future scenarios of emissions and concentrations for greenhouse gases and aerosols. These scenarios are depended on a various approach and contain more consistent short-lived gases and land use variations [17]. Using the medium radiative scenario reach to 4.5 W/m^2 (RCP 4.5) assume stabilizing of emission after year 2100 and high radiative scenario at value 8.5 W/m^2 (RCP 8.5) assume increasing emission scenario after 2100 figure (3). The regional climate model that used in this study is (RCA4) developed by Swedish Meteorology and Hydrological Institute (SMHI). RCA4 is the latest version of the Rossby Center Regional Atmospheric model and can be employed for any domain worldwide. RCA4 model depend on the numerical weather prediction model HIRLAM [18]. Applied the ensemble (r12i1p1) and employed the General Circulation Model (GCM) is (ICHEC-EC-EARTH) as a driving model.

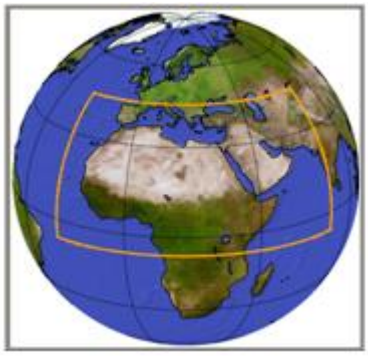

Fig 2. Middle East North Africa (MENA) Domain [15].

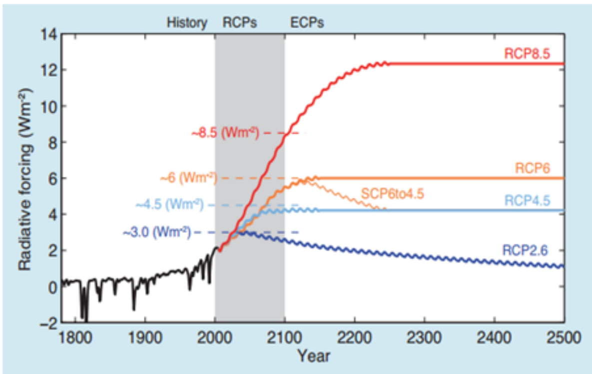

Fig 3. Representative Concentration Pathways (RCP) scenarios [17]

3.3 Bias Correction Approach

The raw outputs from Regional Climate Models (RCM) still include substantial bias, which is inherited from the effect of General Circulation Models (GCMs) or generated via systematic model mistake [19]. These biases appear when comparing between observed data and historical simulation outputs (hindcasted period) from RCMs. The purpose from bias correction is to remove or reducing statistical biases from the forecast datasets [20]. Bias correction approach is necessary in climate impact studies because low calculation request, flexibility and the capacity to improve the match between historical data from RCM and observations. Bias correction technique is assumed to be stationary with time, its meaning the correction algorithm and its parameterization for present climate situations are valid for future situations as well [21]. For current study, bias correction approach were conducted of daily precipitation data from regional climate model RCA4 by utilizing Linear-scaling (mean & standard deviation) equation (1) [22]. Data periods of bias correction were the observed and historical climate model (1979-2005) and future climate model for two mid-21st century (2047-2073) and end- 21st century (2074-2100) under two emission scenarios RCP4.5 and RCP8.5.

$$P_p = (P_s - \bar{P}_s) * \frac{\sigma P_o}{\sigma P_c} + \frac{\bar{P}_o}{\bar{P}_c} * \bar{P}_s \qquad (1)$$

Where P_p is projected future daily precipitation, P_S is daily precipitation of scenario climate model, $\bar{P}_o, \bar{P}_s$ and $\bar{P}_c$ are average daily precipitation of observed, scenario and historical climate model, respectively, σP_o and σP_c are standard deviation of the daily observations and historical model, respectively.

4.Results and discussions

In present study, the daily precipitation data analysis have been conducted for both the observed period covered 1979-2005 and the prediction period which divided to two sub periods: near future 2047-2073 and distant future 2074-2100 under medium and high emission scenarios. Table (1) shows the average annually of rainy days at seven categories, most of precipitation classes demonstrated increasing in rainy days during prediction periods relative to the observed period. Figure (4) and (5) represent the maximum and average daily precipitation over greater zab basin, respectively, for periods: observed, near and distant future under both emission scenario.

Averages daily precipitation have been calculated via divided the annual total precipitation on the number of rainy days which have precipitation higher than 1mm/day. The higher and lower values for maximum and average daily precipitation of study periods at scenarios RCP4.5 and RCP8.5, presented in table (2). The results indicate that likely to be occurred extreme precipitation in future periods over the basin reach to 120 and 132 mm at RCP4.5 and RCP8.5 emission scenario, respectively whereas, during the observed period the maximum daily precipitation was 73 mm.

Table 1. Average annually of rainy days

Precipitation (mm)	Rainy days				
	Observed period 1979-2005	Mid-century (bias corrected) 2047-2073		End-century (bias corrected) 2074-2100	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5
pr >= 1 mm	95.4	124.4	118.6	118.7	117.6
pr >= 5 mm	40.8	42.4	40.6	40.4	39.3
pr >= 10 mm	19.3	20.1	19.3	21.4	18.7
pr >= 20 mm	5.6	6.4	7.9	7.4	6.7
pr >= 30 mm	1.8	2.9	3.4	3.4	3.6
pr >= 40 mm	0.6	1.3	1.8	2.2	2.1
pr >= 50 mm	0.1	0.5	0.9	0.9	0.9

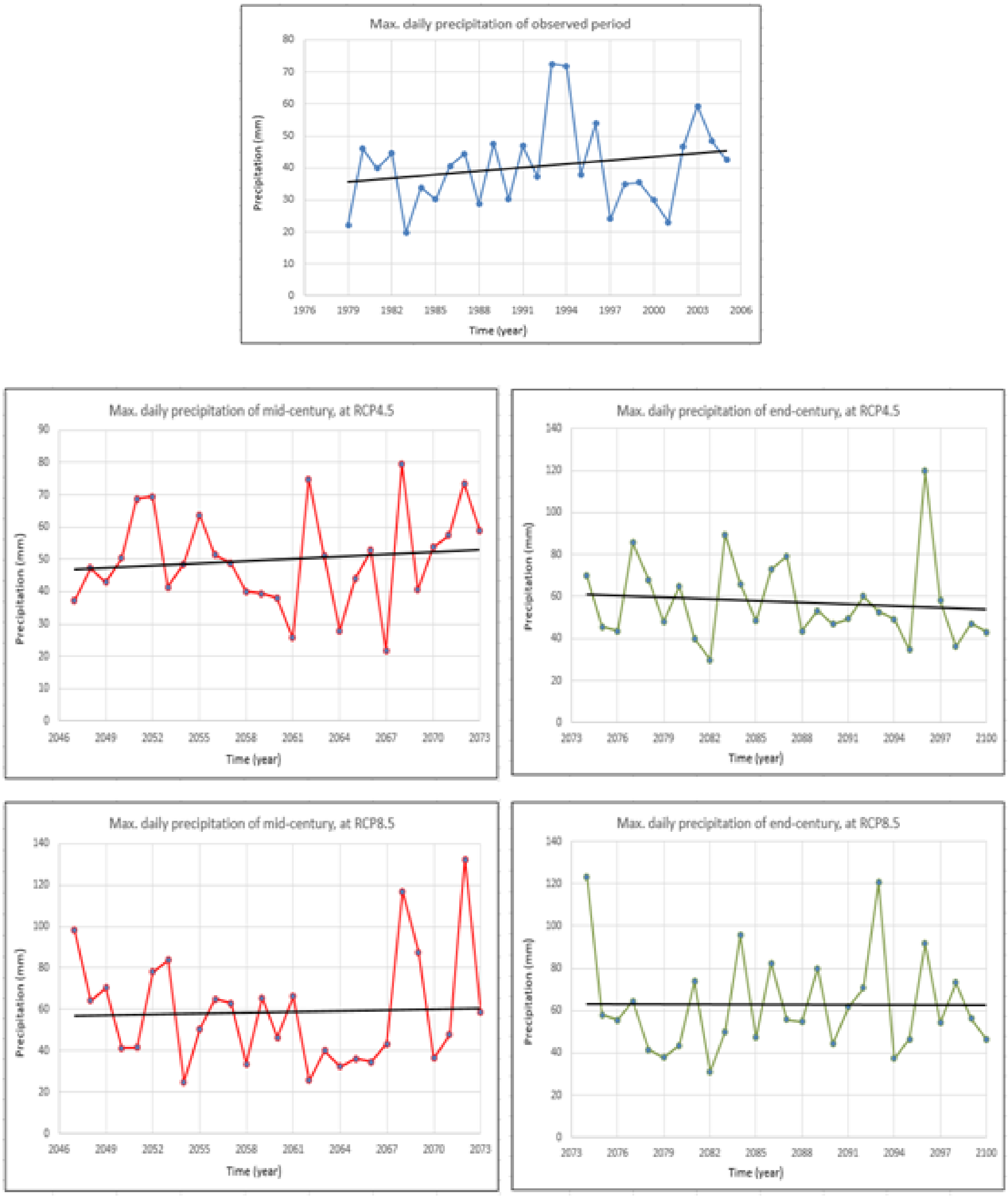

Fig 4. Maximum daily precipitation for observed and prediction periods of the basin.

Table 2. Higher and lower values for maximum and average daily precipitation (mm) during study periods

Daily Precipitation	parameter	observed period	mid-century		end-century	
			RCP4.5	RCP8.5	RCP4.5	RCP8.5
maximum value of each year	higher	73	79	132	120	123
	lower	20	22	25	30	31
average value of each year	higher	9	8	9	9	8
	lower	5	5	5	5	6

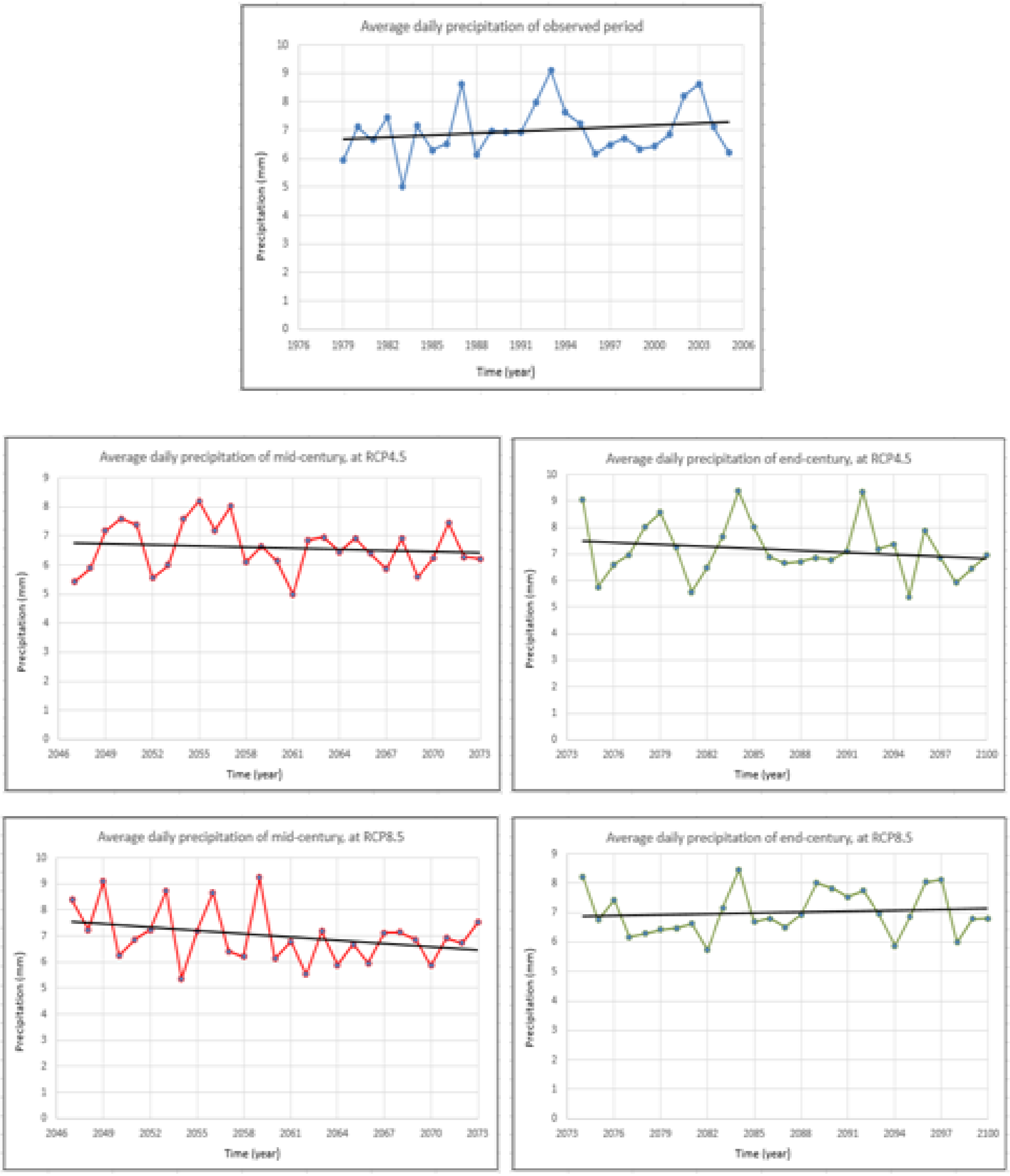

Fig 5. Average daily precipitation for observed and prediction periods of the basin

The outputs from regional climate model RCA4 showed the projections for average monthly of precipitation would be increased in most months under medium and high emission scenarios compared the observed period, figures 6 and 7, respectively. Averages seasonally analysis conducted by employing four season are: winter season (DJF) includes the months December, January and February, spring season (MAM) represents the months March, April and May, summer season (JJA) consists the months Jun, July and August and autumn season comprises a month September, October and November. Table (3) summarized the average seasonally and annually of precipitation during the study periods, during prediction periods most seasons showed rising in total precipitation relative to the observed period. The increasing in average annually of total precipitation as a ratio to the observed period were 23% and 28% under medium scenario whereas, under high scenario were 25% and 23% for mid and end century periods, respectively.

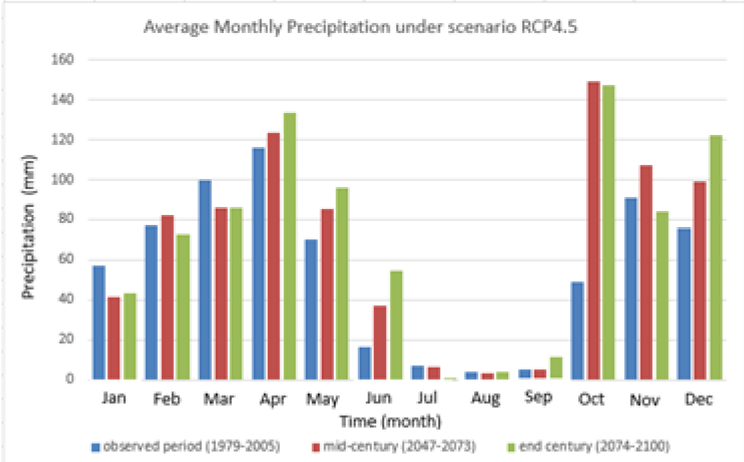

Fig 6. The change of average monthly precipitation under medium emission scenario.

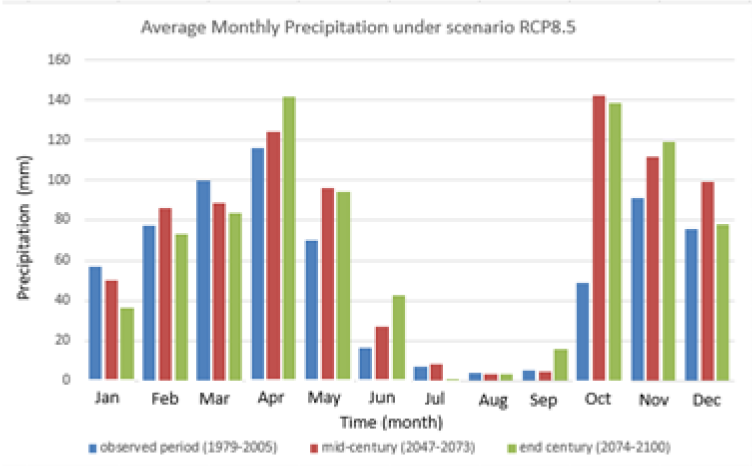

Fig 7. The change of average monthly precipitation under high emission scenario.

Table 3. Average seasonal of precipitation at observed and future periods over the basin.

Seasons	Precipitation (mm)				
	Observed period 1979-2005	Mid-century (bias corrected) 2047-2073		End-century (bias corrected) 2074-2100	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5
DJF	210	222	235	239	187
MAM	286	295	309	315	319
JJA	27	47	38	59	46
SON	145	261	258	243	273
Annual	669	825	841	856	825

5.Conclusion

In this paper we have investigated the responses of the precipitation over the greater zab river basin to global warming through the analysis of regional climate model RCA4 predictions for near (2047-2073) and distant (2074-2100) future periods. Model projections indicate that an increasing in rainy days compared to the observed period. Probability density function (pdf) demonstrated increasing an intensity of daily precipitation for near and distant future periods. Additionally, possible to be occurred extreme precipitation in future periods over the basin reach to 120 and 132 mm under medium and high emission scenarios, respectively whereas, during the observed period the maximum daily precipitation was 73 mm. Regarding average monthly analysis, a maximum precipitation amounts were recorded in October about 140 - 150 mm for forecast period also the same amount was recorded in April during end-21st century at scenario RCP8.5 whereas, for observed period was 116 mm in April month. During the prediction periods, autumn season (SON) was the most rising in precipitation amounts relative to the observed period. Generally, The increasing of average annually of total precipitation as a ratio to the observed period were 23% and 28% under medium scenario whereas, under high scenario were 25% and 23% for mid and end 21st century periods, respectively. Clearly, regional climate model RCA4 predictions demonstrated the characteristics of precipitation would be changed owing to global warming over the greater zab river basin. The indications during the projection periods demonstrated an increasing in precipitation extremes and intensity compared to the observed period. This research can be provides a significant benchmark to assess the performance of regional climate model RCA4 by CORDEX programme in describing future precipitation over the basin. These forecasts would be assist the decision makers to water resource management and in planning and design the hydraulic projects within the basin in future.

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