Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 12, Issue 6, June 2021: 1547-1555

Assessment of Climate Extremes over the Ghataprabha Subbasin of Krishna Basin, India

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Abstract

This study aims at finding changes and climate extremes of precipitation and temperature over a Ghataprabha subbasin (K3) by using indices provides by World Meteorological Organization (WMO) and Expert Team on Climate Change Detection and Indices (ETCCDI). This analysis has been done by using the observed meteorological data and the future projected from CMIP5, global climate models (GCMs) with four time slices under 4 RCPs. The results of annual mean rainfall and daily average maximum temperature shows an increasing trend and daily average minimum temperature shows a fluctuating trend with reference to the baseline period. Climate extreme events were also analyzed for precipitation and temperature. The projected precipitation extremes of highest 1-day (Rx1) and highest 5-day (Rx5) precipitation and number of heavy precipitation days (RR20) shows an increasing trend. Additionally temperature extremes like number of hot days (Tx30GE), number of extremely hot days (Tx35GE) shows an increasing trend and number of hot nights (Tn2LT) shows a fluctuating trend.

Keywords: Precipitation and Temperature Extremes, Ghataprabha sub basin (K3), Global Climate Models (GCMs), Change Factor (CF) Method.

1. Introduction

The increasing populations in both rural and urban areas and rapid industrialization have led to the release of green house gases in the atmosphere, thereby causing the climate change. Changing climate will affect every aspect of nature. From Intergovernmental Panel on Climate Change (IPCC) reports it is observed that many areas in the world were experiencing climate extremes and are likely to increase over many other areas in future. Extreme events in climate (drought, floods, and heat-waves) will leads to the severe and damaging impacts on the environment, health and infrastructures. Thus, in the climate change adaptation and mitigation it is very important to consider the observed and future changes in extreme climate events, in local, national policy making process (Hartmann, et al., 2013; Klein et al., 2006; Menang, 2017). The Ghataprabha sub-basin of Krishna Basin, India was selected for the present study, as it has a semi-arid weather conditions, and more susceptible to change in the climate, prone to the variable rainfall distribution and the warmer atmospheric conditions as well. Nagendra *et al.* 2019 analysed historical trend over Ghataprabha (K3) subbasin using a Non-parametric Mann-Kendal test shows, an increasing trend in annual rainfall for June and August months during Indian Summer Monsoon Rainfall (ISMR) during an observational time period (1901-2016). Hence it is important to study and monitor the present and future changes in climate extremes, (e.g. heat waves intensity and duration, rainfall and temperature extremes) and these needs the high resolution weather data are required. To monitor the climate extremes a set of indices based on observed daily precipitation, maximum and minimum temperature have been developed by the joint WMO (World Meteorological Organisation Commission on Climatology (CCl)/World Climate Research Programme (WCRP) Climate Variability and Predictability project (CLI VAR)/ Joint Commission on Marine Meteorology (JCOMM). (Karl et al., 1999; Zhang et al., 2011; Menang, 2017).

2. AREA OF THE STUDY

Ghataprabha subbasin (K3) lies in the Krishna basin, within northern latitude of 15^0 45' and 16^0 25' and 70^0 and 75^0 55' eastern longitudes (fig. 1). River rises in Western Ghats and flows towards east. It covers an area of about 8829 km^2, the river flows in two states Karnatakaand Maharashtra. Study area falls under semiarid conditions and receives a maximum of 5000mm to a minimum of 600mm and annual mean temperature varies from 25.1 to 26.6 ^{0}C (Biggs *et al.*, 2007).

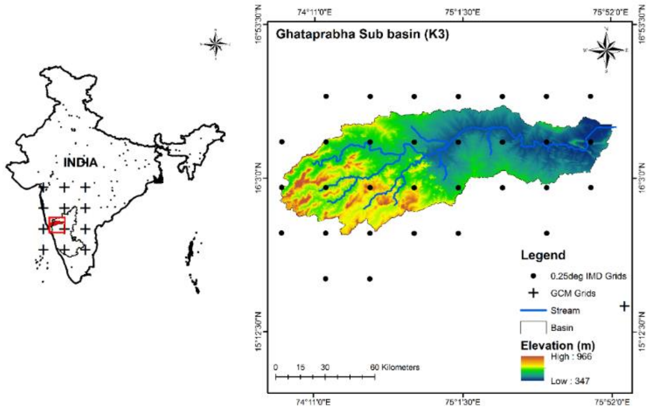

Fig. 1.0 Study area

3. DATA USED

Observed (India meteorological data) and GCMs (CMIP5 models) data are available at different resolutions and the data is extracted for each individual station covering the study area. It is found that 35 stations covering study area considered for assessing extremities of precipitation and temperature over the study region, using high resolution (0.25^0x 0.25^0) daily gridded precipitation and temperature datasets with resolution of (1^0x 1^0) provided by India meteorological Data (IMD). Temperature data is further regridded to 0.25^0 gridded locations using two-dimensional interpolation method by using Matlab programming software to make consistent with precipitation data. Historical period (Observed data) from 1986-2005 (rainfall, temperature) are used and future period consists of 4 different time slices 2021-2040, 2041-2060, 2061-2080, 2081-2100 under 4 different scenarios (RCP 2.6, 4.5, 6.0, 8.5) of ensemble of 5 GCMs from CMIP5 models are used in the analysis. GCMs used in this study are shown in Table 1.

Table 1: Details of GCMs used in the study from CMIP5 datasets.

Sl. No.	Model Name	Grid Resolution	
		Lat	Lon
1.	CSIRO-Mk3.6.0	1.87 x 1.88	
2.	IPSL-CM5A-LR	1.89 x 3.75	
3.	MIROC-ESM	2.79 x 2.81	
4.	MIROC-ESM-CHEM	2.79 x 2.81	

5.	NorESM1-M	1.89 x 2.50

2. METHODOLOGY

In this study some more extreme events of precipitation and temperature were analysed under changing climate. Total 27 core extremes are recommended by the World Meteorological Organization (WMO) and Expert Team on Climate Change Detection and Indices (ETCCDI) (Folland, *et al.*, 2001; Jones, & Hulme, 1996; Peterson, *et al.*, 2001; Teshome, & Zhang, 2019). For this study6 indices of extremes of precipitation and temperature were used (Pongrácz, &Bartholy, 2006) as shown in Table 2.In this study we consider the historical period (Observed data) from 1986-2005 (rainfall, temperature) and future period consists of 4 different time slices 2021-2040, 2041-2060, 2061-2080, 2081-2100 under 4 different scenarios (RCPs 2.6, 4.5, 6.0, 8.5) of ensemble of 5 GCMs from CMIP5 models are used in the analysis. GCMs used in this study are shown in Table 1. Annual mean rainfall and daily average maximum temperature and daily average minimum temperature were also analyzed for historical period (1986-2005) and for future period as well for 4 different time slices under 4 RCPs.

Table 2: List of extreme climate parameters used in the study

Sl.No.	Indicator	Extreme index	Unit
1	Rx1	Highest 1-day precipitation	mm
2	Rx5	Greatest 5-day rainfall total	mm
3	RR20	Number of heavy precipitation days (R_{day} > 20mm)	day
4	Tx30GE	Number of hot days (T_{max}> 30 ^{0}C)	Day
5	Tx35GE	Number of extremely hot days (T_{max}> 35^{0}C)	Day
6	Tn2GT	Number of hot nights (T_{min}> 20 ^{0}C)	Day

4.1 Downscaling of temperature and rainfall

The available GCM data's are of courser resolution, in order to use these models' data for regional scale studies we need to downscale the GCM data. The downscaling procedure used in this study is Change Factor (CF) method (Wilby *et al.*, 2004) and this has been done by using Matlab programming software. The method is also called delta-change method uses the ratios (multiplicative) or differences (additive) relationships between the GCMs historical and future scenarios values, using historical observed values at that location. It has two types Additive CF method (eq. 1) used for temperature (Akhtar *et al.*, 2008; Kilsby *et al.*, 2007) and Multiplicative CF method (eq. 2) used for precipitation as shown below:

$$D_f = D_0 + \left[\left(\overline{GCMf}\right) - \left(\overline{GCMb}\right)\right] \qquad (1)$$

$$D_f = D_0 \times \frac{\overline{GCMf}}{\overline{GCMb}} \qquad (2)$$

Where, D_f is downscaled future variable, D_o is observed historical data, $\overline{GCMf}$ is GCM future climate scenario and $\overline{GCMb}$ the values from a GCM baseline.

5. Results and Discussion

The present study aims at finding changes and climate extremes of precipitation and temperature over Ghataprabha subbasin by using climate indices provided by WMO and ETCCDI. The section discusses the temporal changes in the annual mean rainfall and daily average maximum temperature and daily average minimum temperature of observed period (1986-2005) and projected period under RCP 2.6, 4.5, 6.0 and 8.5 scenarios for the 4 time slices 2021-2040, 2041-2060, 2061-2080, 2081-2100 over Ghataprabha subbasin. It also describes the long-term changes in the extreme rainfall and extreme temperature events for the same time periods. The results of annual mean rainfall (fig. 2) and daily average maximum temperature (fig. 3) shows an increasing trend and daily average minimum temperature (fig. 4) shows a fluctuating trend with reference to the baseline period. Climate extreme events were also analyzed for precipitation and temperature. The projected precipitation extremes namely highest 1-day (Rx1) and highest 5-day (Rx5) precipitation and number of heavy precipitation days (RR20) were analyzed. Temperature extremes like number of hot days (Tx30GE), number of extremely hot days (Tx35GE) and number of hot nights (Tn2LT) and shown in table 3.

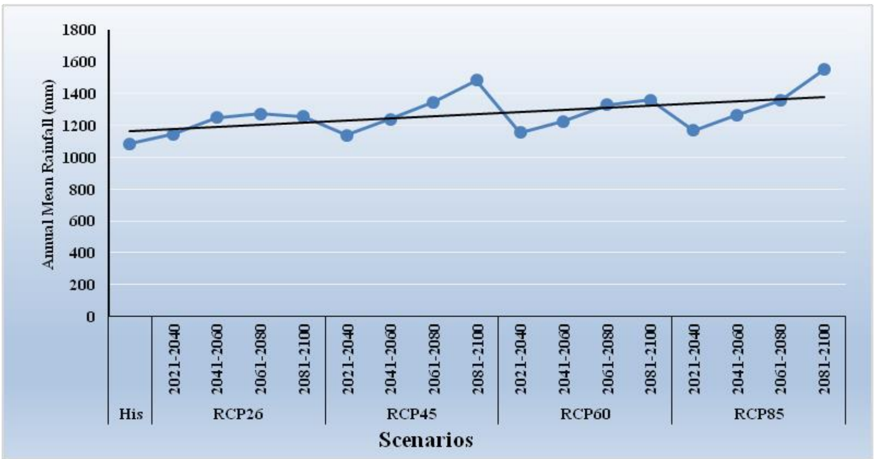

Fig. 2.0 Annual mean rainfall

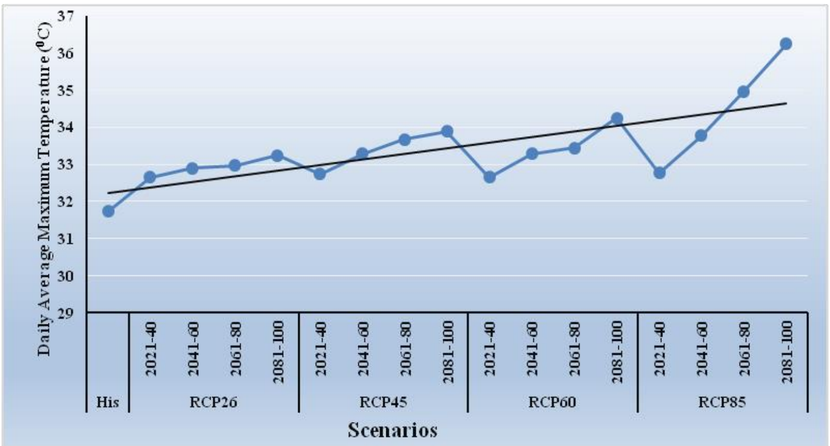

Fig. 3.0 Daily average maximum temperature

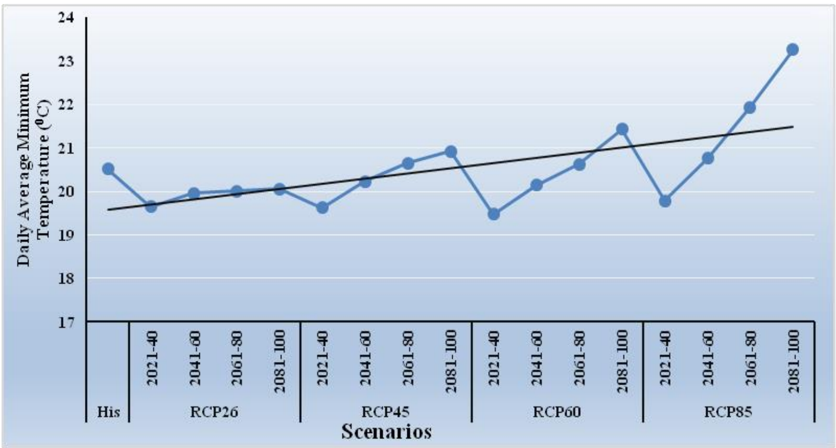

Fig. 4.0 Daily average maximum temperature

Table 3: Projected changes in climate extremities observed relative to historical period.

Climate Driver	Variable	Observation	Future Changes															
			RCP 2.6				**RCP 4.5**				**RCP 6.0**				**RCP 8.5**			
			2021-2040	**2041-2060**	**2061-2080**	**2081-2100**	**2021-2040**	**2041-2060**	**2061-2080**	**2081-2100**	**2021-2040**	**2041-2060**	**2070-2099**	**2081-2100**	**2021-2040**	**2041-2060**	**2061-2080**	**2081-2100**
Precipitation	**Annual Mean Rainfall (mm)**	1085.12	1147.21	1248.50	1271.41	1257.09	1139.35	1239.13	1348.15	1484.20	1157.27	1225.48	1330.34	1359.14	1168.85	1264.80	1357.70	1552.75
	Highest 1-day precipitation (mm)	105.92	114.20	129.09	127.23	118.30	107.79	121.63	129.12	142.56	109.84	133.49	123.95	125.82	157.20	113.28	130.39	111.98
	Greatest 5 day rainfall total (mm)	380.98	399.59	458.27	437.41	438.07	396.88	439.92	455.98	532.28	396.08	426.35	446.47	460.20	546.50	422.22	475.08	404.38
	Number of heavy precipitation days>20mm (days)	164	201	244	252	251	196	250	289	385	207	232	292	303	416	256	309	214
Tempe	**Daily average**	31.73	32.65	32.89	32.96	33.23	32.74	33.28	33.66	33.89	32.65	33.28	33.43	34.24	32.77	33.76	34.95	36.24

	maximum temperature (^{0}C)																	
	Daily average minimum temperature (^{0}C)	20.52	19.65	19.96	20.01	20.06	19.62	20.23	20.65	20.92	19.48	20.15	20.63	21.43	19.78	20.77	21.94	23.26
	Number of hot days Tmax>30(^{0}C)	5199	5993	6115	6073	6237	5958	6273	6470	6558	5945	6326	6415	6845	6048	6537	6990	7247
	Number of extremely hot days Tmax>35(^{0}C)	1371	1745	1838	1953	2124	1825	2070	2229	2408	1770	2038	2132	2536	1792	2262	2943	4196
	Number of hot nights Tmin>20 (^{0}C)	4824	4324	4503	4563	4546	4313	4652	4847	4989	4228	4626	4840	5295	4425	4900	5456	6142

5.1 Climate extremes

5.1b Precipitation extremes

The projected precipitation extremes as shown in table 3 highest 1-day (Rx1) precipitation is increasing gradually under all scenarios especially under RCP 8.5 it is increasing more with respect to observed historical value (fig. 5), and highest 5-day (Rx5) precipitation is increasing significantly under all climate scenarios especially under RCP 8.5 it is increasing more with respect to observed historical value (fig. 6) and number of heavy precipitation days (RR20) shows an increasing trend under all climate scenarios especially showing higher peaks under RP 4.5 and RCP 8.5 more with respect to observed historical value (fig. 7).

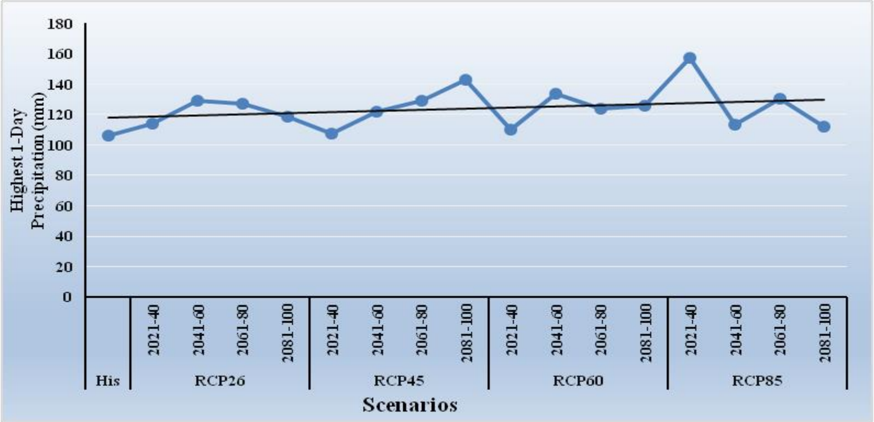

Fig. 5.0 Highest 1-day precipitation

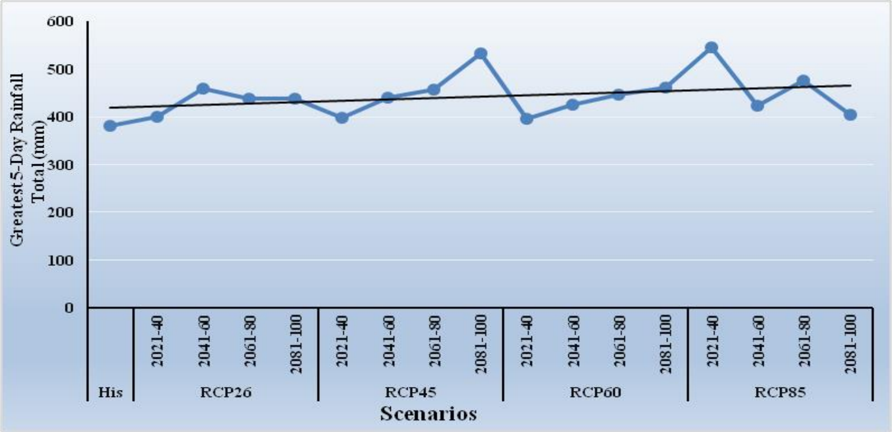

Fig. 6.0 Highest 5-day precipitation

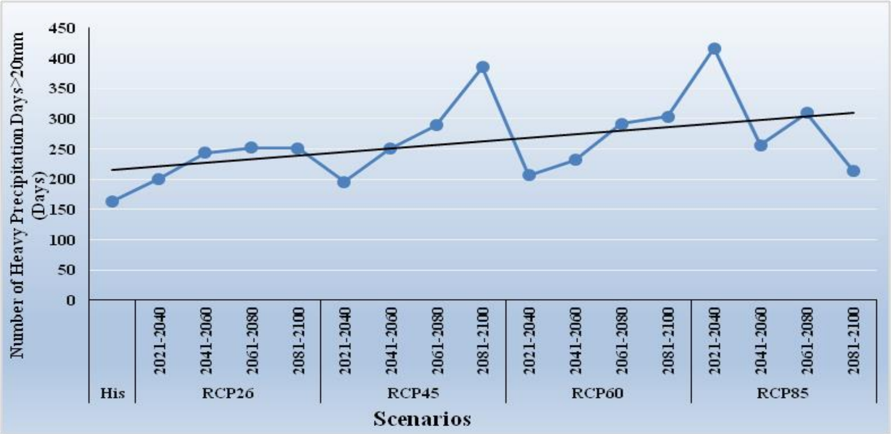

Fig. 7.0 Number of Heavy Precipitation Days>20mm (Days)

5.1b Temperature extremes

Additionally temperature extremes is also analysed with respect to the observed data as shown in table 3 like number of hot days (Tx30GE) is increasing gradually under all scenarios especially under RCP 8.5 it is increasing significantly with respect to observed historical value (fig. 8), number of extremely hot days (Tx35GE) are increasing under all climate scenarios but a significant change in the trend was observed under RCP 8.5 (fig. 9), and number of hot nights (Tn2LT) shows a fluctuating trend as like other extremes it is showing significant increase under RCP 8.5 scenario (fig. 10).

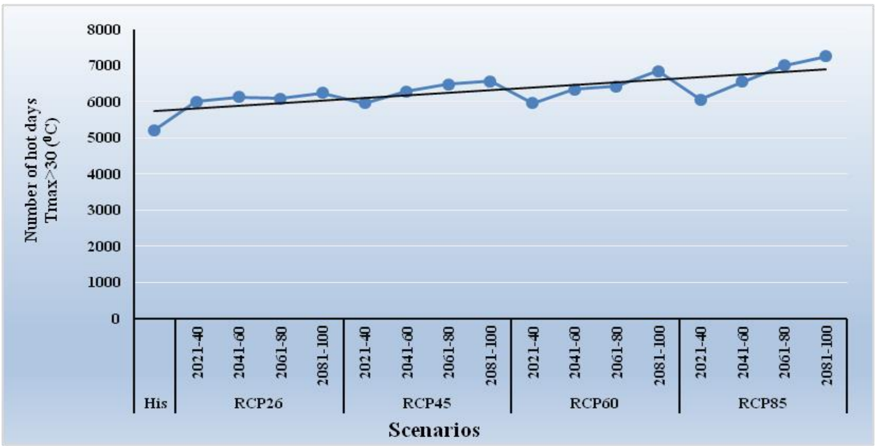

Fig. 8.0 Number of hot days> 30 (^{0}C)

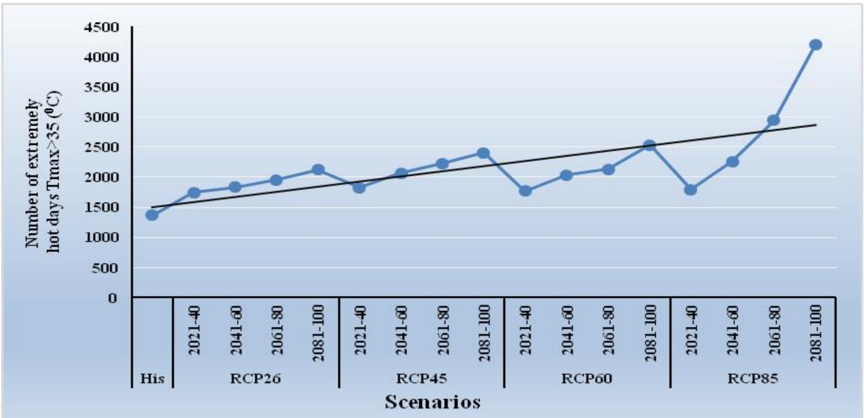

Fig. 9.0 Number of extremely hot days Tmax>35 (^{0}C)

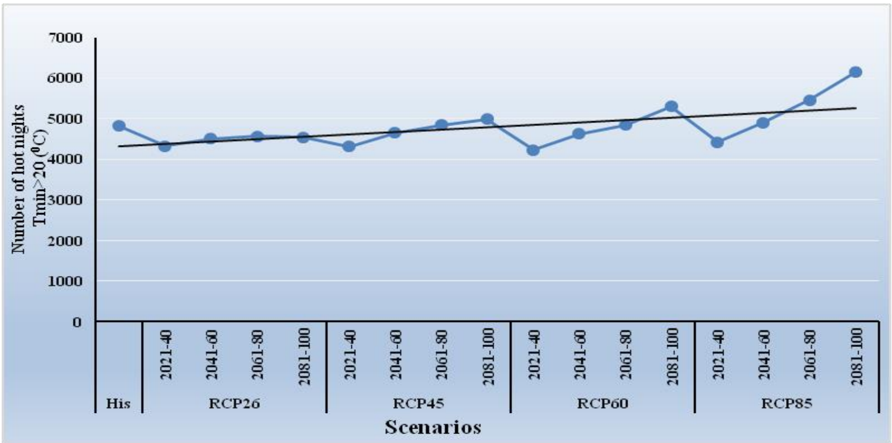

Figure 10. Number of hot nights Tmin>20 (^{0}C)

6. Conclusion

Assessment of historical and future changes in climate extremes of precipitation and temperature carried out with observed data (IMD) and GCM outputs from CMIP5 datasets over the Ghataprabha sub basin (K3) shows an increasing trend for annual mean rainfall and daily average maximum temperature and fluctuating trend for daily average minimum temperature shows a with reference to the baseline period (1986-2005). Climate extreme events were also analyzed for precipitation and temperature. The projected precipitation extremes of highest 1-day (Rx1) and highest 5-day (Rx5) precipitation and number of heavy precipitation days (RR20) shows an increasing trend. Additionally temperature extremes like number of hot days (Tx30GE), number of extremely hot days (Tx35GE) shows an increasing trend and number of hot nights (Tn2LT) shows a fluctuating trend. The further study needs to be extended to assess changes in the water availability in the basin for the policy and sustainable water resource management and to recommend developing effective adaptation strategies.

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