Investigation of precipitation extremes in Dudhnoi river basin, India

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ABSTRACT: A study has been conducted to investigate the precipitation extremes in Dudhnoi river basin using four precipitation based indices- maximum 1-day precipitation amount (Rx1day), number of very heavy precipitation days (R20), consecutive dry days (CDD) and consecutive wet days (CWD) using RClimDex software. The study used daily gridded precipitation data for the period 1981 to 2013 acquired from India Meteorological Department (IMD). Positive trends were found for Rx1day, R20 and CDD indicating increase in maximum 1-day precipitation amount, number of very heavy precipitation (daily rainfall >=20 mm) and consecutive days with rainfall less than 1 mm respectively. Negative trend was observed for consecutive wet days (daily rainfall greater than 1 mm) indicating decrease in the number of wet days. These show that precipitation in the study area are becoming more extremes and concentrated within few rainy days. Intense rainfall, cloudburst, etc. are expected to occur frequently accompanied by long spells of dry period adding pressure on water resources. Hence, it draws the attention of policy makers to endorse appropriate watershed management plans with robust techniques to tackle climate extremes in the future. Also, this study recommends proper management strategies of water resource in the study area.

INTRODUCTION

Of all the natural disasters, disasters caused by extreme meteorological events in the world contributes approximately 85% (Obasi, 1994). Plummer et al. (1999) said that the natural disasters in the world are due to extreme events and not just a variation of climatic means. Thus, it draws a lot of attention to study the climate extremes. The report of Intergovernmental Panel on Climate Change (IPCC, 2013) stated that since 1950 global average maximum and minimum temperatures over land surface have increased by an excess of 0.1 C per decade. Various climate change indicators have been developed in the past and being used for monitoring extreme climatic events such as floods and droughts (Wang et al., 2011). The changing trends of climate extremes required greater importance than trends of mean climate as extreme events as a result of climate change are more intensive and causes catastrophes (Keggenhoff et al., 2014). Expert Team on Climate Change Detection and Indices (ETCCDI) identified 27 core indices based on daily temperature and daily precipitation amount and are

actively used in various studies (Ren et al., 2012; Rao et al., 2014 and Toure et al., 2017). In order to understand the change in pattern of precipitation extremes, a study has been conducted in a mid-sized river basin- Dudhnoi river basin, situated in the north eastern part of India.

STUDY AREA AND DATA

The Duhnoi river basin (Figure 1) contributes runoff and sediments to the river Brahmaputra. The basin covers a geographical area of 476 km^2 sharing between two states of India- Assam (approx. 20%) and Meghalaya (approx. 80%). Daily gridded precipitation data with a spatial resolution of 0.25^o x 0.25^o for the period of 1981 to 2013 were acquired from India Meteorological Department (IMD). The annual average and standard deviation of precipitation in the study area is 2638 mm and 625 mm respectively. The annual average precipitation of the area is very well above the national annual average rainfall of 1190 mm. The topography of the study area is highly undulated for most of its part while a small northern region is flood plain.

METHODOLOGY

Trends of precipitation extremes in the study area were investigated with the help of four precipitation extreme indices (Table 1). A total of 29 grid points were required to cover the study area. A Matlab program was framed to extract and convert from .grd to .txt format. The time series in the .txt format are split for each day from 1981 to 2013 using python. Then, each day precipitation files were converted into shapefiles and then inverse distance weighted (IDW) technique was used to create surface raster of daily precipitation. Further, mean areal precipitation of the basin was calculated using zonal statistic toolbar. After calculating the mean areal precipitation of the basin, each daily precipitation files were converted into .xls format using Excel and CSV Conversion Tools. All the processes are performed iteratively using model builder capability of ArcGIS. Finally, a python script is written to merge all the excels files into a single time series.

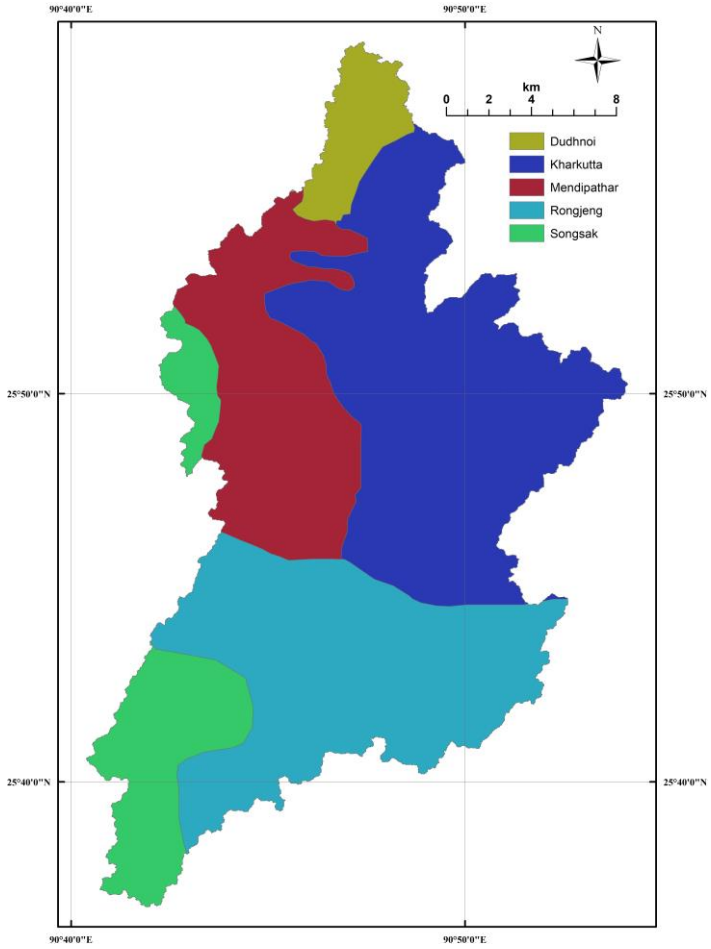

Figure 1: Study area- Duhnoi river basin overlaid by administrative divisions

Out of the 27 core indices identified by ETCCDI, four precipitation base climate extremes indices (Table 1) were chosen for investigation in this study. In recent years, these 27 core indices are extensively used for climate change monitoring and detection studies (Revadekar et al., 2012; Rao et al., 2014; Bothale and Katpatal, 2015 and Tirkey et al., 2018). These four indices were computed using RClimDex-1.9-3 software downloaded from https://github.com/ECCC-CDAS/RClimDex/releases/tag/1.9-3. More details about the indices and its calculation can be found in Zhang et al. (2018) and Tirkey et al. (2018). Quality control analysis was performed inside the RClimDex environment to flag those data which are either missing or outliers. However, no such outliers were found in the data. After calculating the extreme climate indices, a trend analysis has been conducted using a nonparametric Mann-Kendall test (Mann, 1945 and Kendall, 1975). Also, a nonparametric Sen's method (Sen, 1968) was conducted to determine the magnitude of the trend. An excel template MAKESENS 2.0 beta version developed by Salmi et al. (2002) was used to detect trends and determine magnitude of the trends. The results are analysed at 95% confidence interval.

Table 1 Summary of precipitation extremes in the study

Index	Descriptive name	Definitions	Units
Rx1day	Max 1-day precipitation amount	Annual maximum consecutive 1-day precipitation	mm
R20	Number of very heavy precipitation days	Annual count of days when PRCP>=20mm	days
CDD	Consecutive dry days	Maximum number of consecutive days with daily rainfall (RR) <1mm	days
CWD	Consecutive wet days	Maximum number of consecutive days with RR>=1mm	days

RESULTS AND DISCUSSION

The four precipitation extreme indices are plotted in Figure 2 and the trends characteristics given by Mann Kendall's test and Sen's test are given in Table 2. The annual maximum consecutive 1-day precipitation (*Rx1day*) in the area ranges from 36.63 mm in 1981 to 175.46 mm in 2002. Similarly, *CDD*, *CWD* and *R20* ranges from 20 to 127 days, 12 to 127 days and 19 to 80 days respectively. The number of days in which daily rainfall is greater than 20 mm is found highest (80 days) in the year 1998. Wet day i.e. a day when rainfall >= 1 mm occurred continuously for 127 days in the year 1982. Similarly, dry day (daily rainfall < 1 mm) occurred consecutively for 127 days in the year 2013. As illustrated in the figure, *R20*, *CDD* and *Rx1day* are clearly higher in the later period of the study while *CWD* decreases towards the end period.

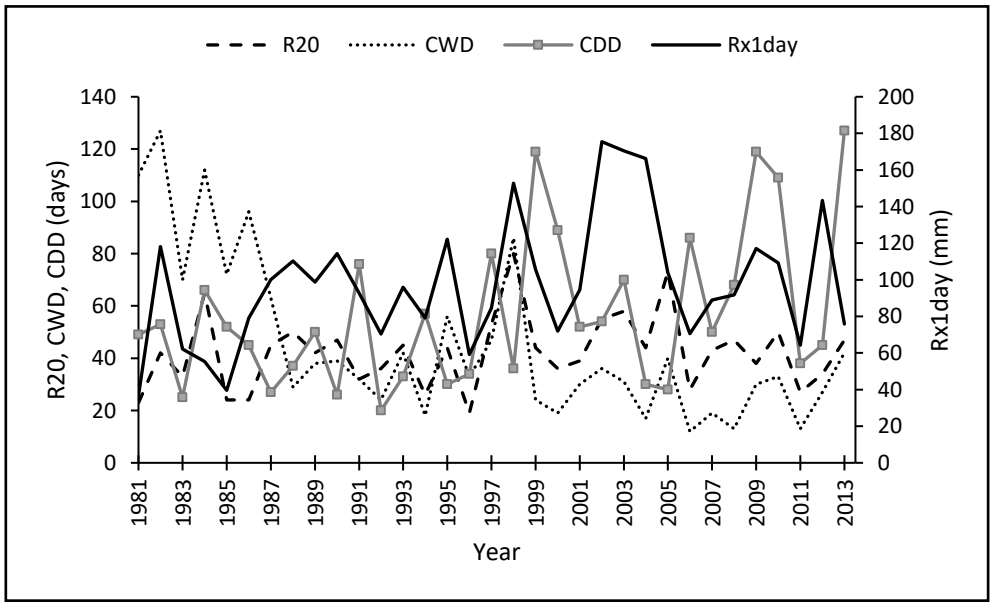

Figure 2 Precipitation extremes in Dudhnoi basin.

Table 2 Mann Kendall's test Z and Sen's slope Q of precipitation extremes (trends significant at 0.05 level are bold)

Precipitation extremes	Mann Kendall's test Z	Sen's slope Q
Rx1day	1.56	1.2
R20	1.08	0.2
CWD	**-3.8**	-1.7
CDD	**2.08**	1.0

The trend analysis of precipitation extremes showed that except for CWD, all other indices followed increasing trends. The results showed that the rate of increment in annual maximum consecutive 1-day precipitation (Rx1day), annual count of days when daily rainfall >=20 mm (R20) and annual maximum number of consecutive days with daily rainfall < 1 mm (CDD) is found as 1.2 mm per year, 0.2 day per year and 1 day per year respectively. And the rate of decline of annual maximum number of consecutive days with RR>=1mm (CWD) occurred at 1.7 days per year. The Z values obtained from the analysis indicated that among the four precipitation extremes, the rate of change of CWD and CDD occurred significantly at 0.05 level. Increasing trend of CDD indicate that the southwest monsoon in the area had been shrinking. These results are indicative of despite decreasing in CWD and increasing in CDD, the precipitation are becoming more and more intense which is evident from the increasing trends of R20 and Rx1day (Table 2). Despite insignificant trends in R20 and Rx1day, it can unarguably state that precipitation of the nature of short duration high intensity is occurring very frequently in the area. This tendency of amplifying response of precipitation extremes such as higher intensity and large amount of precipitation in very short period of time is consistent with the increase of extreme precipitation events globally (Keggenhoff et al., 2014 and Roy and Balling, 2004).

CONCLUSIONS

The present study highlights the changing pattern of precipitation over the Dudhnoi river basin. RClimDex software was used to determine the precipitation extremes. Significant increasing trend at 0.05 level is found for CDD while significant decreasing trend is found for CWD. The rest two indices are following an increasing trend but not significant at 0.05 level. It can be concluded that we can expect extreme climates events such as intense rainfall, cloudburst, etc. to occur more frequently in the study area accompanied by long spells of dry period adding pressure on water resources. Thus, preparedness is required in the area for such unpleasant climate extremes.

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