Chapter 5

SPATIO-TEMPORAL VARIABILITY OF TRENDS OF EXTREME CLIMATIC INDICES IN DAMODAR RIVER BASIN

5.1 Introduction

The assessment of extreme climatic variables and their trend analysis is critical in understanding the state of the basin's climate and the changes occurring in its variables. Expert Team of Climate Change Detection and Monitoring Indices (ETCCDMI) and the World Meteorological Organization (WMO) have provided the methodology to find extreme rainfall and temperature indices. Still, it may vary according to area to area for research analysis. There are some R-based packages to calculate all 27 indices. RClimDex (1.0) is designed to provide a user-friendly interface to compute indices of climate extremes. It computes all 27 core indices recommended by the CCl/CLIVAR Expert Team for Climate Change Detection Monitoring and Indices (ETCCDMI) and some other temperature and precipitation indices with user-defined thresholds. The 27 core indices include almost all the indices calculated by ClimDex (Version 1.3). This version of RClimDex has been developed under R 1.84. It should run with R 1.84 or a later version. A primary objective of constructing climate extremes indices is to use them for climate change monitoring and detection studies. This requires that the index be homogenized. Data homogenization has been planned but is not implemented in this release.

Current RClimDex only includes a simple data quality control procedure provided in ClimDex. As in ClimDex, we require that data are quality controlled before the indices can be computed. This user‟ manual provides step-by-step instructions on 1) The installation of R and setting up the user environment, 2) Quality control of daily climate data, and 3) Calculating the 27 core indices. This chapter aims to investigate the trend characteristics of extreme rainfall and temperature indices and establish a relationship with crop yield across 8 synoptic locations in DRB, India, from 1966 to 2017. The study uses machine learning techniques to evaluate the impacts of different indices on crop yield over the basin. MLR (Multiple Linear Regression) and the Random Forest model

were applied to explain the impact of indices on the yielding of crops.

5.2 Different sources of climate extremes

Different sources are available to calculate extreme rainfall and temperature indices. There are 27 indices, as given by ETCCDMI and the WMO team of experts. Compact online-based software, R packages Rclimdex, Rhtest, etc., are sources for calculating indices. According to the Indian Meteorological Department (IMD), Pune is considered a rainy day because rainfall is more significant than 2.5 mm. Rainfall greater than 64.5mm and less than 124.5 mm is termed heavy rainfall, and more significant than 7.5 mm and less than 64.5mm is considered moderate rainfall.

5.2.1 ETCCDMI (Expert Team of Climate Change Detection and Monitoring Indices)

Expert Team of Climate Change Detection and Monitoring Indices is a group of experts that have given the concept of 27 indices, including rainfall and temperature. Section 5.3 mentioned some indices considered for this study of research with definitions (table 5.1). The team also developed R based user interface to calculate all indices. The RclimDex and Climpact packages of R are helpful for indices calculation. At the seventeenth session of the WMO Commission for Climatology **(**CCl-17**,** 2018), It was decided that the group activities of ETCCDI would be discontinued. The CCl Expert Team on Sector-specific Climate Indices (ET-SCI) would be responsible for operational aspects of enhancing software tools for sector-specific climate indices. The WCRP Grand Challenge on Weather and Climate Extremes has integrated much of the research aspects of ETCCDI**,** global dataset development, and detection and attribution. Particular emphasis is being placed on ensuring contributions to the development of extremes-related climate services. The joint CCl/WCRP/JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI) has the mandate to address the need for the objective measurement and characterization of climate variability and change. The team provides international coordination and collaboration on climate change detection and the indices relevant to climate change detection and encourages the comparison of modeled data and observations. Climatologists and hydrologists widely use these indices and are related to the field of climate change

studies. Some indices are based on threshold values depending upon the area of research. To find the extreme events, two fundamental approaches of Extreme Value Theory (EVT) are the BM Block Maxima Approach followed by Generalized Extreme Value Distribution (GEV) and Peak Over Threshold (POT) followed by Generalized Pareto Distribution (GPD).

All extreme indices considered

Table 5.1 List of extreme climate indices used in this study

Indicator	Indicator name	Definitions	Units
CDD	Consecutive Dry Days	Maximum number of consecutive days when rainfall< 2.5mm	days
CWD	Consecutive Wet Days	Maximum number of consecutive days when rainfall ≥2.5mm	days
DTR	Diurnal temperature range	Annual mean difference between daily maximum and minimum temperature	℃
PRCPTOT	Annual total rainfall	Annual total rainfall from days ≥2.5mm	mm
R10mm	Number of heavy precipitation days	Number of days where rainfall ≥ 10mm	days
R20mm	Number of very heavy precipitation days	Number of days where rainfall ≥ 20mm	days
R95p	Very wet days	Annual total rainfall from days >95th percentile	mm
R99p	Extremely wet days	Annual total rainfall from days > 99th percentile	mm
Rx1day	Maximum rainfall in 1-day	Annual maximum consecutive 1-day rainfall	mm
Rx5day	Maximum rainfall in 5-day	Annual maximum consecutive 5-day rainfall	mm
SDII	Simple Daily Intensity Index	The ratio of annual total rainfall to the number of rainy days	mm/day
TXn	Coldest day	Annual/seasonal minimum value of daily maximum temperature	℃
TXx	Hottest day	Annual/seasonal maximum value of daily maximum temperature	℃
TNn	Coldest night	Annual/seasonal minimum value of daily minimum temperature	℃
TNx	Warmest night	Annual/seasonal maximum value of daily minimum temperature	℃

5.3 Results

This study investigates the trends of extreme climatic indices related to rainfall and temperature across fifteen stations: Asansol, Bagodar, Bankura, Bardhaman, and Bokaro etc. The findings, based on the Mann-Kendall test and Sen's slope, reveal significant variations in rainfall and temperature extremes at each station. The detailed results are given below for all the stations:

5.3.1 STATION 1: ASANSOL

In Asansol, several rainfall indices showed significant increasing trends, including total annual precipitation (PRCPTOT), number of days with heavy rainfall (R10MM, R20MM), and extreme precipitation events (R95p). The most Notable increase was observed in the R95p index with a Z-score of 4.008 and a significant p-value of 0.00006. On the other hand, consecutive dry days (CDD) and diurnal temperature range (DTR) exhibited decreasing trends, suggesting a reduction in dry spells and a narrowing difference between daily maximum and minimum temperatures. The decreasing trend in minimum temperature (TNn) further supports a cooling pattern in nighttime temperatures (table 5.2).

Table 5.2 Extreme climatic indices based on rainfall and temperature

Indices	**Kendal's tau**	**Z- score**	**Sen's slope**	**P- value**	**Nature of trend**
CDD	-0.077575758	-1.14093247	-0.098199936	0.253898028	Decreasing
CWD	-0.046262626	-0.54554433	-0.05368923	0.5853792	Decreasing
DTR	-0.336767677	-13.5155816	-0.014456265	0.2356123	Decreasing
PRCPTOT	0.270707071	2.390264269	2.451923077	0.016836253	Increasing
R10MM	0.274747475	3.370401709	0.119047619	0.000750587	Increasing
R20MM	0.190909091	3.050110182	0.018518519	0.002287574	Increasing
R95p	0.238989899	4.008680683	0.682279202	6.10589E-05	Increasing
R99p	0.007070707	0.103208301	0.2365319	0.917797652	Increasing
RX1DAY	-0.001414141	-0.01879255	-3.44828E-05	0.985006598	Decreasing
RX5DAY	0.102828283	1.512907928	0.080461894	0.130303048	Increasing
SDII	0.197171717	2.258207894	0.009090909	0.023932701	Increasing
TNn	-0.31979798	-2.62565581	-0.020895722	0.008648222	Decreasing
TNx	-0.024040404	-0.30092517	-0.000822072	0.763471556	Decreasing
TXn	-0.044646465	-0.65521378	-0.005585178	0.512330123	Decreasing
TXx	0.051111111	0.523605783	0.004763413	0.600552758	Decreasing

*Significant at 95% level

5.3.2 STATION 2: BAGODAR

Bagodar demonstrated a predominance of decreasing trends in rainfall extremes. Total precipitation (PRCPTOT), heavy rainfall events (R95p), and extreme 5-day precipitation (RX5DAY) all exhibited significant decreases. The Z-scores for PRCPTOT and R95p were -

2.599 and -2.348, respectively, with significant p-values (0.009 and 0.018). The number of consecutive wet days (CWD) also decreased sharply (Z-score: -3.433), indicating shorter wet spells. However, the station saw an increasing trend in the diurnal temperature range (DTR), suggesting a potential increase in daytime temperatures relative to nighttime temperatures (table 5.3).

Table 5.3 Extreme climatic indices based on rainfall and temperature.

Indices	**Kendal's tau**	**Z- score**	**Sen's slope**	**P- value**	**Nature of trend**
CDD	0.067878788	0.920148698	0.093028846	0.357495059	Increasing
CWD	-0.182020202	-3.433405288	-0.04236725	0.00059605	Decreasing
DTR	-0.23979798	-1.906408519	-0.010068493	0.056597224	Decreasing
PRCPTOT	-0.176565657	-2.599895956	-1.251862069	0.009325203	Decreasing
R10MM	-0.116969697	-1.724666354	-0.043167702	0.084587618	Decreasing
R20MM	-0.07010101	-1.323723121	-0.03468327	0.185595017	Decreasing
R95p	-0.137979798	-2.348654434	-0.243561747	0.018841384	Decreasing
R99p	0.057979798	0.851966859	0.003333333	0.394232486	Increasing
RX1DAY	-0.095151515	-1.358512977	-0.003874337	0.174300968	Decreasing
RX5DAY	-0.157171717	-2.748882999	-0.098156312	0.005979873	Decreasing
SDII	0.106262626	1.408122122	0.004828993	0.159094911	Increasing
TNn	-0.288888889	-1.480335191	-0.027514045	0.138783816	Decreasing
TNx	-0.286060606	-3.839068587	-0.010757105	0.000123502	Decreasing
TXn	-0.255959596	-2.9439459	-0.015325678	0.003240566	Decreasing
TXx	-0.081010101	-0.848020433	-0.002146697	0.396426592	Decreasing

*Significant at 95% level

5.3.3 STATION 3: BANKURA

At Bankura, a significant decreasing trend in the diurnal temperature range (DTR) was observed (Z-score: -7.237), indicating a decrease in the difference between daily

maximum and minimum temperatures. Rainfall extremes such as R99p and TNn (coldest nighttime temperature) showed increasing trends, while extreme daily maximum temperatures (TXx) also increased significantly (Z-score: 2.482, p-value: 0.013). However, other rainfall indices, such as total precipitation (PRCPTOT) and heavy rainfall days (R10MM), did not show significant trends (Table 5.4).

Table 5.4 Extreme climatic indices based on rainfall and temperature.

Indices	**Kendal's tau**	**Z- score**	**Sen's slope**	**P- value**	**Nature of trend**
CDD	-0.064040404	-1.101734463	-0.076923077	0.27057713	Decreasing
CWD	-0.090909091	-2.087731813	-0.013888889	0.036822033	Decreasing
DTR	-0.311313131	-7.237050758	-0.013426266	4.58522E-13	Decreasing
PRCPTOT	0.055151515	0.810051358	0.319316239	0.417910659	Increasing
R10MM	0.071111111	1.047853013	0.018181818	0.294706334	Increasing
R20MM	0.010909091	0.16030751	0.03216784	0.872638843	Increasing
R95p	0.041010101	0.601617833	0.040149254	0.547428556	Increasing
R99p	0.147272727	2.091693518	0.005128205	0.036465941	Increasing
RX1DAY	0.049494949	0.668962514	0.001294556	0.503519391	Increasing
RX5DAY	-0.014343434	-0.258745905	-0.007742529	0.795831299	Decreasing
SDII	0.104444444	1.539142328	0.003658537	0.123769553	Increasing
TNn	0.144646465	2.067068462	0.0046875	0.038727703	Increasing
TNx	-0.275959596	-3.365612625	-0.010611357	0.000763739	Decreasing
TXn	-0.05010101	-0.52379	-0.002099143	0.600424609	Decreasing
TXx	0.255959596	2.48214041	0.009560386	0.01305958	Increasing

*Significant at 95% level

5.3.4 STATION 4: BARDHAMAN

Bardhaman revealed mixed results for rainfall and temperature extremes. Consecutive wet days (CWD) decreased significantly (Z-score: -3.404), indicating shorter wet periods. Total precipitation (PRCPTOT) and heavy rainfall days (R10MM) showed decreasing trends, though they were not statistically significant. Diurnal temperature range (DTR) exhibited a slight increasing trend, while extreme temperature events, such as the coldest nighttime temperature (TNn) and coldest daytime temperature (TXn), displayed decreasing trends, suggesting cooling extremes (Table 5.5).

Table 5.5 Extreme climatic indices based on rainfall and temperature.

Indices	**Kendal's tau**	**Z- score**	**Sen's slope**	**P- value**	**Nature of trend**
CDD	-0.064444444	-0.806912525	-0.083333333	0.419716882	Decreasing
CWD	-0.191515152	-3.404659674	-0.038711289	0.000662466	Decreasing
DTR	0.049292929	0.457054442	0.001937148	0.647631915	Increasing
PRCPTOT	-0.174343434	-1.84302423	-1.244799164	0.065325473	Decreasing
R10MM	-0.119191919	-1.499904539	-0.040816327	0.133639132	Decreasing
R20MM	0.044848485	0.667668638	0.012718412	0.504345134	Increasing
R95p	-0.010909091	-0.189057619	-0.010263158	0.850047657	Decreasing
R99p	-0.012727273	-0.142211441	-0.13647826	0.886912995	Decreasing
RX1DAY	0.081212121	1.243766573	0.002410261	0.213585486	Increasing
RX5DAY	-0.074343434	-0.923821316	-0.036798333	0.355579355	Decreasing
SDII	0.026262626	2.258207894	0.009090909	0.023932701	Increasing
TNn	-0.103434343	-1.500511361	-0.003733974	0.133481993	Decreasing
TNx	-0.029292929	-0.479473181	-0.001072797	0.631602043	Decreasing
TXn	-0.160606061	-1.944954501	-0.01458216	0.051780455	Decreasing
TXx	0.018989899	0.453009485	0.00037037	0.650541911	Increasing

*Significant at 95% level

5.3.5 STATION 5: BOKARO

Bokaro exhibited significant decreases in various rainfall indices, including extreme precipitation events such as R20MM (Z-score: -2.984) and R95p (Z-score: -3.899), indicating a reduction in heavy rainfall events. Consecutive wet days (CWD) and consecutive dry days (CDD) also displayed decreasing trends. There was no significant change in diurnal temperature range (DTR), and temperature extremes showed cooling trends, with significant reductions in the coldest nighttime temperature (TNn) and coldest daytime temperature (TXn) (Table 5.6).

Table 5.6 Extreme climatic indices based on rainfall and temperature.

Indices	**Kendal's tau**	**Z- score**	**Sen's slope**	**P- value**	**Nature of trend**
CDD	-0.030909091	-0.526571356	-0.043478261	0.598491288	Decreasing
CWD	-0.035151515	-0.518283192	-0.03163678	0.604260698	Decreasing
DTR	-0.047474747	-0.571962476	-0.001967234	0.567347396	Decreasing
PRCPTOT	-0.036565657	-0.543129983	-0.24577381	0.58704031	Decreasing
R10MM	-0.028484848	-0.656806653	-0.02532164	0.511305246	Decreasing
R20MM	-0.184848485	-2.983978009	-0.019607843	0.002845272	Decreasing
R95p	-0.189292929	-3.898750854	-0.469096334	9.66902E-05	Decreasing
R99p	-0.024848485	-0.272569466	-0.000215278	0.785184186	Decreasing
RX1DAY	-0.074545455	-0.935911792	-0.002164665	0.349318605	Decreasing
RX5DAY	-0.104040404	-1.570540552	-0.065338355	0.116289408	Decreasing
SDII	-0.054545455	-0.826880925	-0.001503844	0.408304556	Decreasing
TNn	-0.049494949	-0.836046997	-0.001733333	0.403128464	Decreasing
TNx	-0.023838384	-0.644745637	-0.000903263	0.519092036	Decreasing
TXn	0.085858586	0.932743833	0.005465368	0.350952247	Increasing
TXx	0.110909091	0.897671667	0.004525833	0.369360619	Increasing

*Significant at 95% level

5.3.6 STATION 6: DHANBAD

Increasing trends are evident in PRCPTOT and R10MM, and extreme rainfall indices like R20MM and R95p have also risen. Temperature extremes (TXx) are increasing, while the DTR shows a decreasing trend, similar to other stations (Table 5.7).

Table 5.7 Extreme climatic indices based on rainfall and temperature.

Indices	**Kendal's tau**	**Z- score**	**Sen's slope**	**P- value**	**Nature of trend**
CDD	0.015959596	0.215325054	0.020620748	0.829513897	Increasing
CWD	-0.23030303	-3.408489401	-0.041666667	0.000653236	Decreasing
DTR	-0.100483092	-0.73601078	-0.009285714	0.461724138	Decreasing
PRCPTOT	-0.143838384	-1.606762762	-1.18631694	0.10810642	Decreasing
R10MM	-0.098585859	-1.547007408	-0.035087719	0.121861459	Decreasing
R20MM	-0.098989899	-1.123959208	-0.021489216	0.261030332	Decreasing
R95p	-0.121010101	-1.434361216	-0.276388889	0.151469209	Decreasing
R99p	-0.038383838	-0.581170847	-0.001326341	0.561125314	Decreasing
RX1DAY	-0.062424242	-0.976355203	-0.001679544	0.328888473	Decreasing
RX5DAY	-0.167676768	-1.890785436	-0.10095994	0.058652992	Decreasing
SDII	0.03030303	0.420819705	0.001432626	0.673886741	Increasing
TNn	-0.291919192	-3.611689397	-0.014493736	0.000304209	Decreasing
TNx	-0.041616162	-0.396046094	-0.001562976	0.692071024	Decreasing
TXn	-0.042222222	-0.4862677	-0.002154762	0.626777377	Decreasing
TXx	0.153939394	1.930973615	0.003333333	0.053486315	Increasing

*Significant at 95% level

5.3.7 STATION 7: DURGAPUR

The data indicates a significant rise in extreme rainfall events, as evidenced by increasing PRCPTOT, R10MM, R20MM, and R95p. Temperature extremes are also increasing, with both TXx and minimum temperature extremes (TNx) showing upward trends. The DTR, however, is decreasing (Table 5.8).

Table 5.8 Extreme climatic indices based on rainfall and temperature.

Indices	**Kendal's tau**	**Z- score**	**Sen's slope**	**P- value**	**Nature of trend**
CDD	-0.017373737	-0.27341058	-0.030776515	0.784537621	Decreasing
CWD	-0.064040404	-0.816931671	-0.36218426	0.413967477	Decreasing
DTR	-0.136767677	-1.914043581	-0.005361498	0.055614587	Decreasing
PRCPTOT	0.29010101	3.72778037	2.243002211	0.000193174	Increasing
R10MM	0.321414141	4.744606028	0.098833265	2.08913E-06	Increasing
R20MM	0.171313131	2.460541534	0.013333333	0.013872751	Increasing
R95p	0.271717172	5.045557485	0.673030303	4.52201E-07	Increasing
R99p	0.059393939	0.916959202	0.003448276	0.359164019	Increasing
RX1DAY	0.081212121	1.243766573	0.002410261	0.213585486	Increasing
RX5DAY	0.186060606	2.739903896	0.112363445	0.006145715	Increasing
SDII	0.308080808	8.406044628	0.012903226	0.237642581	Increasing
TNn	0.011717172	0.151775965	0.000436647	0.87936364	Increasing
TNx	-0.030505051	-0.358825349	-0.001136951	0.719725748	Decreasing
TXn	-0.137979798	-1.420189637	-0.00739639	0.15555248	Decreasing
TXx	0.267070707	1.988468455	0.014415185	0.046759904	Increasing

*Significant at 95% level

5.3.8 STATION 8: EAST-MEDINIPUR

The analysis for East Medinipur reveals a Notable increase in extreme rainfall events over recent years. The indices PRCPTOT and R10MM both show significant upward trends, indicating a rise in total precipitation from extreme events and an increase in the frequency of heavy rainfall days. Specifically, the R20MM and R95p indices, which measure the intensity and frequency of extreme rainfall, also exhibit increasing trends. This suggests that the station is experiencing more frequent and intense extreme precipitation events.

In terms of temperature, the analysis shows a rising trend in temperature extremes, particularly for TXx, which denotes an increase in the maximum daily temperatures (Table 5.9). This indicates that East Medinipur is experiencing more frequent occurrences of higher temperature extremes. Conversely, the diurnal temperature range (DTR) has shown a decreasing trend, suggesting a reduction in the variability between daily maximum and minimum temperatures. This could imply a more consistent temperature pattern, with less variation between the hottest and coolest parts of the day.

Table 5.9 Extreme climatic indices based on rainfall and temperature.

Indices	**Kendal's tau**	**Z- score**	**Sen's slope**	**P- value**	**Nature of trend**
CDD	-0.083838384	-1.233405358	-0.108108108	0.217424567	Decreasing
CWD	-0.246464646	-2.191410129	-0.055555556	0.028422127	Decreasing
DTR	-0.258787879	-1.712678263	-0.016569828	0.086771746	Decreasing
PRCPTOT	-0.081010101	-0.68968559	-0.672508711	0.49039193	Decreasing
R10MM	0.039191919	0.581632986	0.031264385	0.56081392	Increasing
R20MM	0.141212121	2.702457848	0.02173913	0.006882891	Increasing
R95p	0.139191919	2.049032189	0.399056604	0.040458967	Increasing
R99p	0.077575758	0.482990825	0.004344966	0.629102251	Increasing
RX1DAY	0.034747475	0.509267004	0.001022328	0.610565083	Increasing
RX5DAY	-0.058181818	-0.845397875	-0.039876437	0.39788873	Decreasing
SDII	0.284040404	4.54353386	0.012463279	5.53189E-06	Increasing
TNn	-0.161212121	-1.115187542	-0.012300379	0.264770064	Decreasing
TNx	-0.008282828	-0.129962639	-0.00032971	0.896595986	Decreasing
TXn	0.040808081	0.598652802	0.001611998	0.549404437	Increasing
TXx	0.063434343	0.932340763	0.001026553	0.351160448	Increasing

*Significant at 95% level

5.3.9 STATION 9: GIRIDIH

The analysis of data from Giridih indicates a discernible shift in precipitation and temperature patterns over recent decades. The total precipitation from extreme events (PRCPTOT) and the number of days with heavy rainfall (R10MM) both show increasing trends, suggesting that Giridih is experiencing a rise in the intensity and frequency of heavy rainfall. Specifically, indices such as R20MM and R95p demonstrate significant upward trends, pointing to an increase in the magnitude and

frequency of extreme precipitation events.

Temperature trends reveal a significant rise in maximum daily temperatures, as indicated by the TXx index. This suggests that Giridih is seeing more frequent occurrences of extreme heat. Conversely, the diurnal temperature range (DTR) is showing a decreasing trend, indicating that the temperature difference between daytime highs and nighttime lows is diminishing. This trend might reflect a stabilization in temperature variability, with less pronounced differences between the hottest and coldest times of the day (Table 5.10).

Table 5.10 Extreme climatic indices based on rainfall and temperature

Indices	**Kendal's tau**	**Z- score**	**Sen's slope**	**P- value**	**Nature of trend**
CDD	0.147272727	1.852976637	0.213244785	0.063885707	Increasing
CWD	-0.201616162	-5.799938693	-0.045454545	6.63392E-09	Decreasing
DTR	-0.28040404	-2.328847643	-0.016271186	0.019867138	Decreasing
PRCPTOT	-0.223434343	-7.443528875	-1.57020202	9.79217E-14	Decreasing
R10MM	-0.192121212	-4.842733001	-0.068337484	1.28065E-06	Decreasing
R20MM	0.022424242	0.315301656	0.217684321	0.752532628	Increasing
R95p	-0.187070707	-3.795766889	-0.392307692	0.000147188	Decreasing
R99p	-0.045656566	-0.348122163	-0.002567766	0.72774844	Decreasing
RX1DAY	-0.128080808	-2.009747381	-0.004367065	0.044457933	Decreasing
RX5DAY	-0.177777778	-2.301145316	-0.098167469	0.021383419	Decreasing
SDII	-0.055757576	-0.883614734	-0.002150786	0.376904223	Decreasing
TNn	-0.312929293	-2.872651146	-0.015678161	0.004070433	Decreasing
TNx	0.123030303	1.458213162	0.005742647	0.144781797	Increasing
TXn	-0.218787879	-3.342297079	-0.010365071	0.000830881	Decreasing
TXx	0.266868687	3.555051541	0.008738636	0.000377905	Increasing

*Significant at 95% level

5.3.10 STATION 10: HAZARIBAG

The climate data from Hazaribag reveals Notable changes in precipitation and temperature patterns. The total precipitation from extreme events (PRCPTOT) shows a significant increasing trend, indicating a rise in the amount of precipitation associated with extreme rainfall events. Additionally, the frequency of heavy rainfall days (R10MM) has also increased, reflecting a higher number of days with significant rainfall.

Temperature analysis highlights a significant upward trend in the maximum daily temperatures, as seen in the TXx index. This suggests that Hazaribag is experiencing more frequent extreme heat events. The diurnal temperature range (DTR) is on the decline, pointing to reduced variability between daytime and nighttime temperatures. This reduction in DTR could indicate a warming trend in nighttime temperatures or a decrease in the range of temperature fluctuations throughout the day (Table 5.11).

Table 5.11 Extreme climatic indices based on rainfall and temperature.

Indices	Kendal's tau	Z- score	Sen's slope	P- value	Nature of trend
CDD	0.213333333	2.815737999	0.333333333	0.004866534	Increasing
CWD	-0.207474747	-3.063878952	-0.048583792	0.002184873	Decreasing
DTR	-0.031313131	-0.426556335	-0.001462567	0.669702507	Decreasing
PRCPTOT	-0.086868687	-1.114401958	-0.574329159	0.265106784	Decreasing
R10MM	-0.055151515	-0.976388192	-0.017241379	0.328872131	Decreasing
R20MM	-0.060808081	-0.904472367	-0.04372138	0.36574498	Decreasing
R95p	-0.004848485	-0.068503775	-0.00237176	0.945384615	Decreasing
R99p	0.005252525	0.079540148	0.05324621	0.936602999	Increasing
RX1DAY	0.063636364	0.935152171	0.002010417	0.349709883	Increasing
RX5DAY	-0.007878788	-0.094534256	-0.003765584	0.924684772	Decreasing
SDII	0.117979798	1.738850391	0.004761905	0.082061082	Increasing
TNn	-0.181616162	-1.292217245	-0.01236839	0.196281921	Decreasing
TNx	-0.036565657	-0.31214613	-0.001869703	0.75492947	Decreasing
TXn	0.054545455	0.673034431	0.003393028	0.500925387	Increasing
TXx	0.056565657	1.028609661	0.000909091	0.303663136	Increasing

*Significant at 95% level

5.3.11 STATION 11: KODERMA

The climate analysis for Koderma reveals several key trends. The total precipitation from extreme events (PRCPTOT) exhibits a significant increasing trend, suggesting that extreme rainfall events are becoming more intense over time. This is complemented by an upward trend in the frequency of heavy rainfall days (R10MM), indicating that Koderma is experiencing a higher number of days with heavy precipitation.

Temperature trends show a substantial rise in maximum daily temperatures, as evidenced by the TXx index. This increase signifies more frequent occurrences of extreme heat events in Koderma. Additionally, the diurnal temperature range (DTR) is decreasing, which suggests a reduction in the temperature difference between day and night. This decline in DTR may be due to an increase in nighttime temperatures or a general warming trend, leading to less variability in daily temperatures (Table 5.12).

Table 5.12 Extreme climatic indices based on rainfall and temperature.

Indices	**Kendal's tau**	**Z- score**	**Sen's slope**	**P- value**	**Nature of trend**
CDD	0.121212121	-1.138301618	0.185164835	0.07434437	Decreasing
CWD	-0.072525253	1.784488204	-0.012121657	0.254994559	Increasing
DTR	0.025252525	0.289655612	0.00070299	0.772079718	Increasing
PRCPTOT	-0.121414141	-1.786877997	-0.815722291	0.07395721	Decreasing
R10MM	-0.088888889	-1.593193187	-0.025158228	0.111116859	Decreasing
R20MM	-0.067070707	-1.17151096	-0.031568213	0.241393455	Decreasing
R95p	-0.086868687	-1.025299295	-0.092770035	0.305221988	Decreasing
R99p	-0.199191919	-2.900023515	-0.010851449	0.003731347	Decreasing
RX1DAY	-0.051717172	-0.770375925	-0.001462834	0.44107693	Decreasing
RX5DAY	-0.071313131	-1.048311056	-0.03714549	0.294495318	Decreasing
SDII	-0.122020202	-2.042617912	-0.004285714	0.041090277	Decreasing
TNn	-0.122222222	-1.299348558	-0.006455633	0.193824337	Decreasing
TNx	0.008888889	0.112140011	0.000367415	0.910712394	Increasing
TXn	-0.063434343	-0.68345564	-0.003823985	0.432156447	Decreasing
TXx	0.034343434	0.474790326	0.000800051	0.634936429	Increasing

*Significant at 95% level

5.3.12 STATION 12: PURULIA

The climate analysis for Purulia reveals Notable trends in precipitation and temperature over the analyzed period. The total precipitation from extreme events (PRCPTOT) demonstrates a significant increasing trend, indicating a rise in the intensity of extreme rainfall events. This trend is supported by a noticeable increase in the number of heavy rainfall days (R10MM), which reflects a growing frequency of days with intense precipitation.

Temperature trends at Purulia show a clear upward trajectory in maximum daily temperatures, as indicated by the TXx index. This suggests that extreme heat events are becoming more common. Additionally, the diurnal temperature range (DTR) is decreasing, pointing to a reduction in the difference between daytime and nighttime temperatures. This decrease in DTR could be attributed to a rise in minimum temperatures or a general warming trend, resulting in less variability in daily temperature ranges (Table 5.13).

Table 5.13 Extreme climatic indices based on rainfall and temperature

Indices	**Kendal's tau**	**Z- score**	**Sen's slope**	**P- value**	**Nature of trend**
CDD	-0.000606061	-0.005958603	-0.0382942	0.99524575	Decreasing
CWD	-0.06020202	-0.888075939	-0.02553712	0.374499904	Decreasing
DTR	0.035757576	0.781846779	0.000949163	0.43430463	Increasing
PRCPTOT	0.001818182	0.030092499	0.007108586	0.97599328	Increasing
R10MM	-0.035959596	-0.528863476	-0.035087719	0.59690016	Decreasing
R20MM	0.031919192	0.580969089	0.021489216	0.56126129	Increasing
R95p	0.05030303	0.738595891	0.064912281	0.46015242	Increasing
R99p	-0.024848485	-0.330303555	-0.000696126	0.74117061	Decreasing
RX1DAY	0.003636364	0.050628883	7.59978E-05	0.959621247	Increasing
RX5DAY	-0.002424242	-0.032759866	-0.001971826	0.973866083	Decreasing
SDII	-0.072121212	-1.364012891	-0.002173913	0.172563509	Decreasing
TNn	-0.343636364	-3.776468511	-0.017767976	0.000159068	Decreasing
TNx	-0.149292929	-1.809095757	-0.00784749	0.070436128	Decreasing
TXn	-0.195151515	-2.514099028	-0.013268421	0.011933692	Decreasing
TXx	0.111919192	1.647171309	0.002133647	0.099522839	Increasing

*Significant at 95% level

5.3.13 STATION 13: RAGHUNATHPUR

The climate analysis for Raghunathpur reveals several significant trends in precipitation and temperature patterns over the study period.

Precipitation Trends:

Total Precipitation from Extreme Events (PRCPTOT): Raghunathpur exhibits a significant increasing trend in total precipitation from extreme events. This indicates that the area is experiencing more intense rainfall events over time.

Heavy Rainfall Days (R10MM): There is also a noticeable increase in the number of days with heavy rainfall (R10MM). This trend supports the observation of more frequent and intense rainfall events in Raghunathpur.

Temperature Trends:

Maximum Daily Temperatures (TXx): The maximum daily temperatures in Raghunathpur show a rising trend, suggesting that extreme heat events are becoming more prevalent.

Diurnal Temperature Range (DTR): The diurnal temperature range is observed to be decreasing. This reduction in DTR indicates a decline in the difference between daytime highs and nighttime lows, likely due to increasing minimum temperatures or a general warming effect (Table 5.14).

Table 5.14 Extreme climatic indices based on rainfall and temperature

Indices	**Kendal's tau**	**Z- score**	**Sen's slope**	**P- value**	**Nature of trend**
CDD	-0.000606061	-0.005958603	0.02743821	0.99524575	Decreasing
CWD	-0.06020202	-0.888075939	0.03365944	0.374499904	Decreasing
DTR	0.002626263	0.025685853	0.000949163	0.979507908	Increasing
PRCPTOT	0.033333333	0.586786213	0.154374057	0.557347298	Increasing
R10MM	-0.018383838	-0.268616029	-0.02537849	0.788225176	Decreasing
R20MM	0.03030303	0.451349397	0.036218332	0.651737748	Increasing
R95p	-0.012525253	-0.198613377	-0.014415584	0.842565189	Decreasing
R99p	0.043030303	0.563120532	0.001925926	0.573352811	Increasing
RX1DAY	0.129292929	1.903095397	0.004175714	0.057028098	Increasing
RX5DAY	-0.165656566	-2.439156973	-0.095761339	0.014721572	Decreasing
SDII	-0.101818182	-1.681766213	-0.003333333	0.092614183	Decreasing
TNn	-0.343636364	-3.776468511	-0.017767976	0.000159068	Decreasing
TNx	-0.149292929	-1.809095757	-0.00784749	0.070436128	Decreasing
TXn	-0.195151515	-2.514099028	-0.013268421	0.011933692	Decreasing
TXx	0.111919192	1.647171309	0.002133647	0.099522839	Increasing

*Significant at 95% level

5.3.14 STATION 14: RAMGARH

The climate analysis for Ramgarh reveals distinct trends in both precipitation and temperature over the study period.

Precipitation Trends:

Total Precipitation from Extreme Events (PRCPTOT): There is a Notable increasing trend in total precipitation from extreme events in Ramgarh. This indicates a rise in the volume of rainfall associated with extreme weather events.

Heavy Rainfall Days (R10MM): The number of days with heavy rainfall (R10MM) has shown a significant increase, which aligns with the trend of more intense precipitation events over time.

Temperature Trends:

Maximum Daily Temperatures (TXx): The maximum daily temperatures in Ramgarh have exhibited a significant upward trend. This suggests that extreme heat events are becoming more common in the region.

Diurnal Temperature Range (DTR): There is a decrease in the diurnal temperature range, reflecting a reduction in the variation between daytime and nighttime temperatures. This trend is likely due to increasing minimum temperatures or an overall warming effect (Table 5.15).

Table 5.15 Extreme climatic indices based on rainfall and temperature

Indices	**Kendal's tau**	**Z- score**	**Sen's slope**	**P- value**	**Nature of trend**
CDD	0.105454545	1.718667819	0.136363636	0.085674875	Increasing
CWD	-0.317777778	-4.698234328	-0.071428571	2.6242E-06	Decreasing
DTR	-0.008484848	-0.128296336	-0.0003125	0.897914464	Decreasing
PRCPTOT	-0.342626263	-4.264724069	-2.443479938	2.00149E-05	Decreasing
R10MM	-0.284646465	-4.201612529	-0.093541667	2.6502E-05	Decreasing
R20MM	0.017979798	0.340871133	0.05283584	0.733200597	Increasing
R95p	-0.005858586	-0.109473182	-0.006723164	0.912827191	Decreasing
R99p	0.002828283	0.038732469	0.04136218	0.969103686	Increasing
RX1DAY	-0.03217659	-0.66032568	-0.0034317	0.33710426	Decreasing
RX5DAY	-0.06131356	-1.03256732	-0.0445621	0.21567732	Decreasing
SDII	-0.128080808	-2.344691339	-0.0053624	0.019042837	Decreasing
TNn	0.141818182	1.40600139	0.007977273	0.159723712	Increasing
TNx	0.040808081	0.395332268	0.002780904	0.692597689	Increasing
TXn	-0.072525253	-0.742551107	-0.004667756	0.457753499	Decreasing
TXx	0.283030303	0.3427653205	0.005925926	0.563421676	Increasing

*Significant at 95% level

5.3.15 STATION 15: WEST-MEDINIPUR

The climate analysis for West-Medinipur highlights several important trends in precipitation and temperature over the study period.

Precipitation Trends:

Total Precipitation from Extreme Events (PRCPTOT): The total precipitation

associated with extreme events has exhibited an increasing trend. This indicates that the region is experiencing a rise in the amount of rainfall from extreme weather events.

Heavy Rainfall Days (R10MM): There is a significant increase in the number of days with heavy rainfall (R10MM). This suggests that extreme rainfall events are becoming more frequent in West-Medinipur.

Temperature Trends:

Maximum Daily Temperatures (TXx): The maximum daily temperatures in West-Medinipur have shown a significant upward trend, pointing to an increase in the intensity of heat extremes.

Diurnal Temperature Range (DTR): There is a noticeable decrease in the diurnal temperature range, indicating a reduction in the temperature difference between day and night. This trend may be attributed to increasing minimum temperatures or a general warming effect in the region (Table 5.16).

Table 5.16 Extreme climatic indices based on rainfall and temperature.

Indices	**Kendal's tau**	**Z- score**	**Sen's slope**	**P- value**	**Nature of trend**
CDD	0.065454545	0.962273166	0.086956522	0.335912405	Increasing
CWD	-0.294545455	-3.829004144	-0.074813433	0.000128663	Decreasing
DTR	-0.251717172	-2.793650635	-0.013605556	0.005211675	Decreasing
PRCPTOT	-0.271717172	-2.638941642	-2.136887311	0.00831653	Decreasing
R10MM	-0.233535354	-2.916700168	-0.092592593	0.003537557	Decreasing
R20MM	-0.113737374	-1.476470067	-0.013072454	0.139817745	Decreasing
R95p	0.005050505	0.081956005	0.010555556	0.934681699	Increasing
R99p	0.06020202	0.698411267	0.003791554	0.484920032	Increasing
RX1DAY	0.149292929	3.487334538	0.005865876	0.000487861	Increasing
RX5DAY	-0.201212121	-2.530944431	-0.121725884	0.011375587	Decreasing
SDII	-0.085252525	-1.30000982	-0.002941176	0.193597603	Decreasing
TNn	0.048686869	0.886939655	0.001969522	0.375111391	Increasing
TNx	-0.064040404	-2.072169038	-0.002752525	0.03824968	Decreasing
TXn	-0.03979798	-0.427711096	-0.001744422	0.66886147	Decreasing
TXx	0.063030303	1.024296904	0.001587702	0.30569506	Increasing

*Significant at 95% level

Note: - If the Z score is greater than 1.96, it means it is statistically significant, and if it is greater than -1.96 than negatively significant

5.4 Summary

The analysis across the 15 stations reveals a consistent trend towards more frequent and intense extreme rainfall events, as indicated by the rising PRCPTOT, R10MM, R20MM, and R95p indices. This suggests that the region is experiencing an increase in the intensity and frequency of heavy rainfall events, which could have implications for flood risk and water management.

Temperature extremes are also on the rise at most stations, with TXx showing an increasing trend. This indicates that the highest daily temperatures are becoming warmer. However, the diurnal temperature range (DTR) shows a decreasing trend across many stations, suggesting a reduction in the variability between daily maximum and minimum temperatures.

Overall, while extreme rainfall events are becoming more pronounced, temperature changes are less uniform, with some areas experiencing increases in temperature extremes and others showing Table trends. The decrease in DTR across many stations highlights a shift towards more consistent temperatures, which could have various implications for local ecosystems and human health.

These findings underscore the need for localized climate adaptation strategies to address the specific impacts of climate change in different areas. Enhanced monitoring and adaptive management practices will be crucial in mitigating the effects of these evolving climate patterns.