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Block Wise Trend Analysis and Extreme Events in Raipur District, India

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The study was conducted in four blocks viz. Abhanpur, Arang, Raipur, and Tilda of Raipur district, using IMD gridded rainfall and maximum (Tx) and minimum (Tn) temperature data from 1951 to 2019. Trend analysis was performed with three non-parametric methods (Mann Kendall, Spearman's Rho, and Innovative Trend Analysis (ITA)) and one parametric test (Linear Regression analysis) for annual and seasonal rainfall and temperature. Extreme weather events were studied using Weather Cock and RClimdex software, calculating sixteen climatic indices. The data was divided into 1951-1986 and 1987-2019. The results demonstrated a significant decreasing trend ($p<0.01$) in rainfall by 10 to 15%. Maximum temperature had a significant increasing trend and minimum temperature significantly decreased ($p<0.01$) as per ITA. Other methods indicated non-significant decreasing trends for minimum temperature. ITA proved more effective in trend detection. The value of all indices differed before and after 1986, indicating noticeable climate changes. Increasing Warmer days, colder nights, and an expanding diurnal temperature range were observed, accompanied by increased heat wave incidence. Moderate drought episodes and all severe drought occurrences increased after 1986. The values of maximum and minimum temperatures reached new peaks. These findings highlight significant climate changes in the study area, emphasizing the need for sustainable climate management and adaptation strategies.

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1. INTRODUCTION

Climate change refers to the long-term alteration of Earth's climate patterns due to human activities and natural processes. The unprecedented release of greenhouse gases, such as carbon dioxide, methane, and nitrous oxide, from industrial activities, deforestation, and agriculture has intensified the greenhouse effect, leading to global warming. This rise in temperature triggers various adverse effects, including extreme weather events, melting glaciers and ice caps, rising sea levels, and disruptions to ecosystems. The consequences of climate change are far-reaching, affecting biodiversity, agriculture, water resources, and human health. The findings from climate studies are crucial for understanding the impacts of climate change on the environment, biodiversity, and human societies. By providing crucial insights into the causes and consequences of global warming, these studies play a vital role in formulating effective mitigation and adaptation strategies, fostering sustainable practices, and shaping policies to combat the pressing challenges of our changing climate [1]. In climate studies, trend analysis plays a vital role. Trends in the climatic parameters will give us an idea of where we are going and whether it is detrimental or normal [2].

Trend analysis of rainfall and temperature plays a critical role in understanding the long-term climate patterns and potential impacts of climate change. By analyzing historical data from meteorological records and climate models, scientists can discern trends and variations in rainfall and temperature over extended periods. Such analysis helps to identify shifts in weather patterns, such as increasing or decreasing rainfall trends and rising temperatures, which can signal the onset of climate change. It also aids in uncovering regional and global climatic anomalies and can provide early warning signs for extreme weather events like droughts, heat waves, and floods.

Furthermore, trend analysis allows researchers to establish the relationship between rainfall and temperature changes. For example, it helps identify whether there are links between reduced rainfall and rising temperatures in certain regions, leading to water scarcity and potential ecological consequences. Understanding these relationships is crucial for devising effective adaptation and mitigation strategies to address the challenges posed by climate change.

Governments and policymakers use trend analysis to inform climate policies and develop plans for sustainable resource management and disaster preparedness. Moreover, businesses and industries utilize this data to assess potential risks and opportunities arising from climate shifts, thereby promoting climate resilience and responsible decision-making.

Overall, trend analysis of rainfall and temperature provides a solid scientific foundation for climate research, policy formulation, and societal response to the ongoing climate crisis. It serves as a key tool in enhancing our understanding of climate dynamics and working towards a more sustainable and climate-resilient future. There are many tests to identify the trend. We have taken four methods: Mann Kendall, Spearman’s Rho, Linear Regression Analysis, and Innovative Trend Analysis (ITA). Among these ITA was the recent one introduced by Sen in 2011 [3], gains more popularity in hydrometeorological trend analysis in recent years. Analyzing different methods and comparing results from different methods will help better to identify the trend. To strengthen the results of trend analysis, a detailed analysis of rainfall and temperature in various aspects like meteorological drought, dry spells and wet spells, warmer days and colder days, etc., will give a more elaborate picture of the situation. Eg. Rainfall may show decreasing trend but whether it is due to a decrease in rainfall amount or due to a decrease in the number of rainy days matters.

Extreme weather events analysis involves the examination of severe and unusual climatic phenomena to understand their frequency, intensity, and underlying causes. Scientists analyse historical records, satellite data, and climate models to identify patterns and trends in extreme events like hurricanes, heatwaves, droughts, floods, and wildfires. By comprehending the factors driving these events, such as climate change, atmospheric conditions, or natural variability, researchers can provide valuable insights for disaster preparedness, risk assessment, and climate adaptation strategies. RClimdex software facilitates precise calculation of climate extreme indices, enabling researchers to quantitatively assess the frequency, intensity, and duration of extreme weather events. This aids in robust risk analysis, guiding effective climate adaptation and disaster preparedness strategies for enhanced resilience and mitigation of extreme risks. When the spatial scale is small, the practical utility of the research will be high, hence this study is carryout at the block level in the Raipur district. This study focuses on the performance of selected trend analysis methods and various climatic indices.

2. MATERIALS AND METHODS

Raipur, the capital of Chhattisgarh, is located between the latitude of 21° 93″ to 21° 63″ longitude of 81° 19″ to 81° 53″ at an elevation ranging from 244 to 409 m from Mean Sea Level. It has four blocks i.e. Arang, Abhanpur, Raipur, and Tilda. The total area of Raipur is 2892 sq. km. The mean annual rainfall of the Raipur district is 1370 mm. The South West monsoon period is the dominant rainy season.

Gridded data of rainfall (0.25◦x 0.25◦), maximum and minimum temperature (0.50◦x 0.50◦) of the study area were collected from the India Meteorological Department website. The block-wise rainfall and temperature data were calculated using the weighted average method. The study covered the period from 1951 to 2019, during which climatic indices analysis was conducted in two phases: one before 1986 and another after 1986.

2.1 Trend Analysis

For trend analysis TREND and R studio software were used. Trend detection was carried out using three non-parametric tests viz. Mann-Kendall, Spearman's Rho, and Innovative Trend Analysis, and a parametric test Linear regression.

2.1.1 Mann-Kendall test

This method tests whether there is a trend in the time series data. It is a non-parametric test [4]. The n time series values (X1, X2, X3, ….., Xn) are replaced by their relative ranks (R1, R2, R3, ….., Rn) (starting at 1 for the lowest up to n). (Kendall, M.G.1975) (Yadav et al., 2014).

2.1.2 Spearman's rho

This rank-based test determines whether the correlation between two variables is significant [5]. In trend analysis, one variable is taken as the time itself (years) and the other as the corresponding time series data. Their ranks replace time series values (Meshram et al., 2017).

2.1.3 ITA test

It's a distribution-free cartesian diagram test introduced by Sen in 2011 [3]. In order to apply this graphical test, the first half of the entire time series is plotted against the second half. If the plotted to scatter points lie on a 1:1 line (45° straight line), it means there is no trend in the time series. On the contrary, scatter points above or below the 1:1 line indicate increasing or decreasing monotonic trends, respectively. In this test, the slope (s) of the trend is calculated according to the following expression [3] (Singh et al., 2021).

2.1.4 Linear regression test

Parametric test in which data were assumed to be normally distributed. Examining the relationship between time (x) and the variable of interest (y) and whether there is a linear trend existing was figured out. The linear regression test assumes that the data are normally distributed and that the errors (deviations from the trend) are independent and follow the same normal distribution with zero means.

2.2 Analysis of Extreme Weather Events

Weather Cock is a software program developed by *Ramamohan and Rao et.,* under AICRPAM. It has various analysis modules for rainfall and temperatures among which three were used here.

2.2.1 Agricultural Drought (AD) (Kharif drought)

At least four consecutive weeks receiving less than half of the normal rainfall (>5mm).

2.2.2 Meteorological drought

It is generally rainfall deficiency based on the level of deficiency from normal rainfall it is classified into three categories.

Mild ≤ 25%, Medium (MMD) 26-50%, and Severe (SMD) >50%

2.2.3 Heat wave

Heat Wave is not considered until Tmax reaches 40℃ in Plains and 30℃ in Hilly regions.

When Tmax remains at 45℃, a heat wave is declared irrespective of the normal Tmax.

Table 1a. Heat wave criteria

	When normal Tmax ≤40℃	When normal Tmax ≥40℃
Heat wave	Departure from normal is 5℃ to 6℃	Departure from normal is 4℃ to 5℃
Severe heat wave	Departure from normal is 7℃ or more	Departure from normal is 6℃ or more

Table 1b. Indices calculated using RClimdex

ID	Indicator name	Definitions	UNITS
CDD	Consecutive dry days	Maximum number of consecutive days with RR<1mm	Days
CSDI	Cold spell duration indicator	Annual count of days with at least 6 consecutive days when TN<10th percentile	Days
CWD	Consecutive wet days	Maximum number of consecutive days with RR>=1mm	Days
DTR	Diurnal temperature range	The monthly mean difference between TX and TN	ºC
TN10p	Cool nights	Percentage of days when TN<10th percentile	Days
TN90p	Warm nights	Percentage of days when TN>90th percentile	Days
TNn	Min Tmin	The monthly minimum value of the daily minimum temp	ºC
TNx	Max Tmin	The monthly maximum value of the daily minimum temp	ºC
TX10p	Cool days	Percentage of days when TX<10th percentile	Days
TX90p	Warm days	Percentage of days when TX>90th percentile	Days
TXn	Min Tmax	The monthly minimum value of the daily maximum temp	ºC
TXx	Max Tmax	The monthly maximum value of the daily maximum temp	ºC
WSDI	Warm spell duration indicator	Annual count of days with at least 6 consecutive days when TX>90th percentile	Days

RR = Rainfall, TX = Maximum Temperature and TN = Minimum Temperature

2.2. 4. RClimdex Indices

The software was developed by *Xuebin Zhang and Feng Yang* at the Climate Research Branch of the Meteorological Service, Canada. CCl/CLIVAR Expert Team for Climate Change Detection Monitoring and Indices (ETCCDMI). RClimdex 1.0 version was used in this research and among 27 indices available 13 were taken here (Table 1b.). These indices were used by various scientists [6-8], (Kaur et al., 2022) and (Pavithrapriya et al., 2022)

3. RESULTS AND DISCUSSION

Detailed results of trend analysis for four blocks of Raipur is given in Table 2.

3.1 Trend of Temperatures

The analysis reveals a significant increasing trend in the maximum temperature for Abhanpur on both annual and all seasonal scales. In Arang, the annual, NE, and SW monsoon periods display a significant increasing trend, whereas summer shows a non-significant trend, and winter exhibits a non-significant decreasing trend. These findings align with the results presented by Sanjay et al. [9]. Similarly, in Raipur, significant increasing trends were observed annually and in all seasons except for winter, where the trend was non-significant but increasing. The trend analysis for the Tilda block shows similarities with that of the Raipur block.

In the Abhanpur block, the SW monsoon season and winter seasons exhibited a non-significant increasing trend, whereas the other seasons displayed a non-significant decreasing trend. In Arang, all seasons, except for NE, showed a non-significant decreasing trend, while SW had a significant decreasing trend. The same pattern of results was observed in both the Raipur and Tilda blocks. These findings indicate distinct trends in different seasons across the studied regions, with some seasons, showing a slight increase and others displaying a mild decrease, while SW monsoon in Arang stands out with a significant decreasing trend.

3.2 Trend of Rainfall

The analysis of rainfall trends reveals interesting patterns across the studied regions. In terms of rainfall trends, Abhanpur exhibited a significant increasing trend during NE, Winter, and summer seasons, but annually, it showed a decreasing trend primarily attributed to a significant decrease in SW monsoon [10]. In Arang, the annual rainfall displayed a significant decreasing trend, while NE and winter experienced a non-significant increasing trend, and SW and summer showed non-significant decreasing trends. In Raipur, all seasons, except for winter, showed a non-significant decreasing trend, whereas winter had a non-significant increasing trend. Similarly, in Tilda, significant decreasing trends were observed during annual and SW monsoon seasons, which align with the results reported by Swain et al., [10]. Additionally, NE and Summer monsoon seasons experienced non-significant decreasing trends, whereas the winter season displayed a non-significant increasing trend. These findings highlight the varying patterns of rainfall changes across different seasons and regions, emphasizing the importance of considering seasonal trends while analysing climate data.

3.3 Drought Analysis

In the Arang block, there has been an increase in agriculture drought, indicating a concerning trend for the agricultural sector. On the contrary, the Raipur block has not experienced any significant change in agriculture drought levels. However, in Abhanpur and Tilda, there has been a decreasing trend in agriculture drought, offering some relief to the agricultural communities in those regions. In the Raipur district, both medium and severe meteorological droughts have shown a significant 50% increase, raising concerns about water availability and crop productivity. Additionally, all severe droughts were recorded only after 1986, highlighting a shift in drought frequency and intensity in recent years. These findings underscore the importance of drought monitoring and management strategies to support sustainable agriculture and water resource planning in the affected regions.

3.4 Results of Rainfall-Based Indices

The results of all the indices were calculated and represented in Table 3. Both the CSDI (Cold Spell Duration Index) and WSDI (Warm Spell Duration Index) indicate increasing trends in all blocks, implying a shift toward more extreme temperature events. Cold spells have slightly increased by 1 to 2 days in most blocks, except for Abhanpur, where there was a mild decrease of less than a day. Conversely, warm spells have exhibited a significant rise, with an alarming rate of 10 to 15 days increase, leading to more consecutive hot days, particularly noticeable after 1986. Heatwaves have also seen an increase by 4 days in all blocks, emphasizing the intensification of extreme heat events.

Regarding CDD (Consecutive Dry Days) and CWD (Consecutive Wet Days), there has been a reduction of 1 to 2 days in all blocks, suggesting shifts in precipitation patterns. Both consolidated rainfall days and the total amount of rainfall have shown decreasing trends, mainly attributed to a reduction in the South West monsoon season, which has experienced 2 to 5 fewer rainfall days on average and a notable 3-day reduction during the SW months. Additionally, the total rainfall amount has reduced by 100 to 175mm, accounting for 10 to 15% of the average rainfall amount, with a more significant reduction observed during the SW monsoon season. These findings highlight the changing climate conditions and the impact of reduced rainfall on the studied regions, signaling potential challenges for water resources and agriculture in the future.

3.5 Results of Temperature-Based Indices

According to Sanjay et al. [9], after 1986, the minimum nighttime temperature (TNn) in all blocks decreased by 0.3℃, and the maximum daytime temperature (TXn) reduced by 0.2℃, except for Abhanpur, where it increased by 0.2℃. Moreover, the maximum nighttime temperature (TNx) was reduced by 0.5℃ in all blocks, and the maximum daytime temperature (TXx) increased by 0.4℃ across all blocks. These results indicate that maximum temperatures were continuously increasing, reaching new peaks, while minimum temperatures were considerably decreasing [11]. This trend resulted in an increased Diurnal Temperature Range of 0.5℃, signifying that the difference between maximum and minimum temperatures has widened.

The analysis shows that both warmer days and cold nights have increased annually, with 5 more warm days and 2 more cold nights compared to previous decades. Conversely, warm nights and cold days have been reduced by 1 to 2 days and 2 to 3 days annually. In terms of season-wise trends, winter tops the list with 7 to 8 more warm days, while the rest of the seasons experience 3 to 5 additional warm days. In terms of cold nights, the South West season experiences a significant increase of 7 days, possibly due to increased moisture availability after a long dry season. However, this phenomenon may also result from increased high-temperature ranges before rainfall, leading to a sudden drop in temperatures. These findings underscore the changing temperature patterns, with maximum and minimum temperatures pushing their limits and resulting in colder nights and warmer days than in previous decades.

Table 2. Results of trend analysis

Test	Abhanpur					Arang					Raipur					Tilda				
	Rainfall																			
	A	W	S	SW	NE	A	W	S	SW	NE	A	W	S	SW	NE	A	W	S	SW	NE
MK	S (*)	S(**)	S (**)	NS	S (**)	S (**)	NS	NS	NS	NS	NS	NS	NS	NS	NS	S (*)	NS	NS	S (*)	NS
SR	S (*)	S (**)	S (**)	NS	S (**)	S (**)	NS	NS	NS	NS	NS	NS	NS	NS	NS	S (*)	NS	NS	S (*)	NS
R	S (*)	S (**)	S (**)	NS	S (**)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	S (**)	NS	NS	S (**)	NS
ITA	S (**)	NS	S (‘)	S (‘)	NS	S (**)	S (**)	S (**)	S (‘)	S (*)	S (**)	S (**)	S (**)	S (**)	NS	S (**)	S (‘)	S (**)	S (**)	NS
Maximum Temperature																				
	A	W	S	SW	NE	A	W	S	SW	NE	A	W	S	SW	NE	A	W	S	SW	NE
MK	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	NS	NS	S(**)	S(**)	S(**)	NS	S (*)	S(**)	S(**)	S(**)	NS	S (*)	S(**)	S(**)
SR	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	NS	NS	S(**)	S(**)	S(**)	NS	S(**)	S (*)	S(**)	S(**)	NS	S(**)	S (*)	S(**)
R	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	NS	NS	S(**)	S(**)	S(**)	NS	S (*)	S (*)	S(**)	S(**)	NS	S (*)	S (*)	S(**)
ITA	NS	S(**)	S (‘)	S (*)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)
Minimum Temperature																				
	A	W	S	SW	NE	A	W	S	SW	NE	A	W	S	SW	NE	A	W	S	SW	NE
MK	NS	NS	NS	NS	NS	NS	NS	NS	S (*)	NS	NS	NS	NS	S (*)	NS	NS	NS	NS	S (‘)	NS
SR	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
R	NS	NS	NS	NS	NS	NS	NS	NS	S (*)	NS	NS	NS	NS	S (*)	NS	NS	NS	NS	NS	NS
ITA	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)

Note: (‘)- Significant at 0.1 confidence interval level ,(*)- significant at 0.05 confidence interval level, (**) – Significant at 0.01 confidence interval level
S / S = Significant increasing/decreasing trend at 0.05 or 0.01 level of the confidence interval
NS / NS = non-significant increasing/decreasing trend at 0.05 or 0.01 level of the confidence interval

Table 3. Results of RClimdex and weather cock indices

Indices	Abhanpur			Arang			Raipur			Tilda		
	<86	>86	Difference	<86	>86	Difference	<86	>86	Difference	<86	>86	Difference
AD	4	2	2	3	5	2	3	3	0	3	2	1
CDD	110.6	109.0	1.6	108.1	107.3	0.7	100.0	91.1	8.9	48.3	47.1	1.1
CWD	14.4	12.3	2.1	17.1	15.3	1.8	17.1	15.3	1.7	14.3	13.2	1.1
CSDI	6.8	6.1	0.7	7.5	10.2	2.7	7.5	10.2	2.7	8	10.2	2.2
HW	38.2	42.3	4.1	37.1	41.2	4.1	37.1	41.6	4.5	37.1	41.6	4.5
MMD	4	6	2	3	4	1	4	7	3	3	7	4

Indices	Abhanpur			Arang			Raipur			Tilda		
	<86	**>86**	**Difference**	**<86**	**>86**	**Difference**	**<86**	**>86**	**Difference**	**<86**	**>86**	**Difference**
SMD	0	1	1	0	1	1	0	0	0	0	1	1
TNn	6.9	6.5	0.4	6.8	6.5	0.3	6.8	6.5	0.3	6.9	6.5	0.3
TNx	29.8	29.3	0.5	29.9	29.3	0.5	28.8	28.3	0.5	29.9	29.3	0.5
TXn	22.1	21.8	0.2	22.2	22.0	0.2	22.2	22.0	0.2	21.9	21.7	0.2
TXx	43.6	44.0	0.4	43.7	44.1	0.4	43.7	44.1	0.4	43.6	44.1	0.4
WSDI	6.4	16.4	9.9	10.8	24.7	13.9	10.8	24.7	13.9	9.8	24.7	14.9
	Consolidated Rainfall (Days)											
Annual	71.0	66.3	4.7	73.2	69.0	4.2	68.6	66.0	2.6	68.2	65.4	2.8
Winter	1.8	1.5	0.3	1.7	1.5	0.1	1.5	1.8	0.2	1.6	1.5	0.1
Summer	4.5	3.0	1.4	3.8	3.2	0.5	3.8	3.8	0	3.1	3.0	0.1
SW	60.1	57.5	2.5	63.3	60.0	3.2	58.7	55.9	2.7	59.4	56.7	2.7
NE	4.5	4.5	0	4.2	4.3	0.1	4.4	4.5	0.1	4.0	4.2	0.2
	Consolidated Rainfall (Amount)											
Annual	1270.5	1093.8	176.7	1201.6	1107.8	93.83	1210.6	1105.9	104.7	1175.7	1022.5	153.1
Winter	15.3	14.8	0.5	14.2	17.3	3.0	16.0	19.5	3.4	14.8	16.0	1.2
Summer	49.1	27.3	21.7	36.7	28.9	7.8	39.4	35.5	3.9	33.3	28.5	4.8
SW	1147.4	996.1	151.3	1097.0	1008.0	88.97	1097.9	993.8	104.1	1077.7	924.8	152.9
NE	62.7	56.4	6.3	55.6	53.9	1.7	57.0	60.1	3.1	52.9	54.3	1.4
	Diurnal Temperature Range											
Annual	12.3	12.9	0.5	12.5	13.0	0.5	12.5	13.0	0.5	12.3	12.9	0.6
Winter	14.9	15.3	0.4	15.1	15.7	0.6	15.1	15.7	0.6	15.0	15.6	0.6
Summer	15.1	15.4	0.3	15.3	15.8	0.5	15.3	15.8	0.5	15.2	15.8	0.6
SW	8.0	8.6	0.6	8.2	8.6	0.4	8.2	8.6	0.4	8.0	8.5	0.5
NE	13.6	14.4	0.8	13.7	14.2	0.5	13.7	14.2	0.5	13.5	14.0	0.5
	TXp 90 warm days (in percentage of days)											
Annual	6.4	11.5	5.1	9.3	14.2	4.9	9.3	14.2	4.9	9.1	14.6	5.5
Winter	5.8	12.8	7.0	10.1	18.1	8.0	10.1	18.1	8.0	9.9	17.0	7.1
Summer	6.1	11.2	5.1	9.1	13.3	4.2	9.1	13.3	4.2	9.0	14.0	4.9
SW	6.4	11.7	5.2	8.8	14.2	5.4	8.8	14.2	5.4	8.7	14.8	6.0
NE	7.0	10.7	3.6	9.7	12.6	2.8	9.7	12.6	2.8	9.3	13.6	4.2

Indices	Abhanpur			Arang			Raipur			Tilda		
	<86	**>86**	**Difference**	**<86**	**>86**	**Difference**	**<86**	**>86**	**Difference**	**<86**	**>86**	**Difference**
	TNp 90 warm nights (in percentage of days)											
Annual	11.0	8.8	2.2	9.9	8.7	1.2	9.9	8.7	1.2	9.6	8.7	0.8
Winter	9.5	9.5	0	10.4	8.9	1.4	10.4	8.9	1.4	10.8	8.9	1.8
Summer	10.6	8.6	1.9	11.1	7.4	3.6	11.1	7.4	3.6	11.2	7.5	3.7
SW	11.8	8.3	3.5	11.1	9.5	1.5	11.1	9.5	1.5	10.9	9.5	1.3
NE	11.0	8.4	2.6	9.9	8.8	1.0	9.9	8.8	1.0	9.6	8.8	0.7
	TXp 10 cold days (in percentage of days)											
Annual	12.3	9.12	3.2	11.2	8.7	2.5	11.2	8.7	2.5	11.4	8.6	2.7
Winter	9.9	9.4	0.4	10.3	9.4	0.9	10.3	9.4	0.9	10.2	9.1	1.0
Summer	11.5	8.9	2.6	10.5	8.5	1.9	10.5	8.5	1.9	11.0	8.3	2.6
SW	11.8	9.4	2.4	11.2	9.7	1.4	11.2	9.7	1.4	11.5	9.5	1.9
NE	15.3	8.5	6.7	12.5	6.8	5.7	12.5	6.8	5.7	12.3	7.1	5.1
	TNp 10 cold nights (in percentage of days)											
Annual	8.5	10.7	2.1	10.2	12.4	2.2	10.2	12.4	2.2	10.3	12.4	2.1
Winter	11.8	10.6	1.1	12.2	13.7	1.5	12.2	13.7	1.5	12.0	13.8	1.8
Summer	10.8	9.1	1.6	10.1	10.8	0.7	10.1	10.8	0.7	9.9	10.8	0.8
SW	5.0	11.7	6.7	7.9	15.11	7.1	7.9	15.1	7.1	8.1	15.1	6.9
NE	9.0	10.7	1.7	12.0	9.5	2.5	12.0	9.5	2.5	12.4	9.4	3.0

Increasing trend; Decreasing trend

3.6 Evaluation of ITA

Among the four trend detection methods (Mann-Kendall, Spearman's Rho, ITA, and Linear regression), ITA generally follows a similar pattern as that of others, but there are instances where its results differ significantly from the other methods. For example, in rainfall analysis for Abhanpur, ITA detected a non-significant decreasing trend in winter and NE, while the other three methods showed a significant increasing trend. Similarly, for maximum temperature in Arang during winter, the other three methods indicated a non-significant increasing trend, but ITA alone showed a significant decreasing trend. The same discrepancy was noticed in the minimum temperature for summer and SW in Abhanpur, where the other three methods detected a decreasing trend, while ITA alone showed an increasing trend at a 0.01 confidence level. However, when compared with the indices results, ITA was found to be more precise and accurate than the other methods, as reported by Sanikhani et al. [12].

This disparity in results might be attributed to ITA's unique approach of splitting the data sets into two halves and rank-based plotting [13]. This process helps to reduce errors caused by the continuous stretching of data and may provide a more robust trend analysis. Despite the divergent results in certain cases, ITA's ability to produce more accurate and refined outcomes in other scenarios suggests its potential as a valuable tool for trend detection, especially when dealing with complex and varied data sets [14].

4. CONCLUSION

In conclusion, the comprehensive analysis based on various tests consistently indicates an increasing trend in the overall maximum temperature across all time periods. Additionally, a notable decrease in rainfall trends, particularly during the South West monsoon season, was observed. The study also revealed a decline in minimum temperatures, leading to the expansion of the diurnal temperature range. Moreover, the findings highlight a concerning rise in the incidence of extreme weather events in the study area. These trends collectively point to the ongoing impacts of climate change in the region, emphasizing the urgency of implementing adaptive measures and climate-resilient strategies to mitigate the potential adverse effects on ecosystems and communities.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Leal Filho W, Nagy GJ, Setti AFF, Sharifi A, Donkor FK, Batista K, Djekic I. Handling the impacts of climate change on soil biodiversity. Science of the Total Environment. 2023;869:161671.
2. Agnolucci P, De Lipsis V. Long-run trend in agricultural yield and climatic factors in Europe. Climatic Change. 2020;159:385-405
3. Şen Z. Innovative trend analysis methodology. Journal of Hydrologic Engineering. 2011;17(9):1042–1046.
4. Mann HB. Nonparametric tests against trend. Econometrica. 1945;13(3):245.
5. Spearman C. The proof and measurement of association between two things. Source: The American Journal of Psychology. 1904;15(1):72–101.
6. Shrestha AB, Bajracharya SR, Sharma AR, Duo C, Kulkarni A. Observed trends and changes in daily temperature and precipitation extremes over the Koshi river basin 1975–2010. International Journal of Climatology. 2017;37(2).
7. Agnihotri I, Punia MP, Sharma JR. Assessment of spatial variations in temperature and precipitation extremes in west-flowing river basin of Kutch, Saurashtra and Marwar, India. Current Science. 2018;114(2).
8. Dubey SK, Sharma D. Spatio-temporal trends and projections of climate indices in the Banas river basin, India. Environmental Processes. 2018;5(4).
9. Sanjay J, Revadekar JV, Ramarao MVS, Borgaonkar H, Sengupta S, Kothawale DR, Patel J, Mahesh R, Ingle S. Temperature changes in India. Assessment of Climate Change over the Indian Region: A Report of the Ministry of Earth Sciences (MoES), Government of India. 2020:21–45.

10. Swain S, Verma M, Verma MK. Statistical trend analysis of monthly rainfall for Raipur district, Chhattisgarh. International Journal of Advanced Engineering Research and Studies. 2015;IV(II):87–89.
11. Dash SK, Mamgain A. Changes in the frequency of different categories of temperature extremes in India. Journal of Applied Meteorology and Climatology. 2011;50(9).
12. Sanikhani H, Kisi O, Mirabbasi R, Meshram SG. Trend analysis of rainfall pattern over the Central India during 1901–2010. Arabian Journal of Geosciences. 2018;11(15).
13. Talukdar S, Pal S, et al. Trend analysis and forecasting of streamflow using random forest in the Punarbhaba river basin. Environmental Monitoring and Assessment. 2023;195(1):153.
14. Malik A, Kumar A, Guhathakurta P, Kisi O. (). Spatial-temporal trend analysis of seasonal and annual rainfall (1966–2015) using innovative trend analysis method with significance test. Arabian Journal of Geosciences. 2019;12:1-23.

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