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Spatial and Temporal Variation of Rainfall and Temperature in Sambalpur District of Odisha

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

The research was conducted to determine the extent of climate change in Sambalpur district, Odisha from the year 1990 to 2019. The climate change was studied for rainfall and temperature by running Mann-Kendall test at 5% significance level on time series data for each of the 9 blocks for the time period 1990 to 2019. The resultant Mann-Kendall test statistics indicated how strong the trend in rainfall and temperature was and whether it was increasing or decreasing. For seasonal rainfall six of the nine blocks showed increasing trend but only 3 blocks showed significant increasing trend. Similarly, for maximum temperature six of the nine blocks showed increasing trend and of these six blocks five blocks showed significant increasing trend. For temperature extreme ≥ 40°C, the trend was increasing but insignificant. For temperature extreme ≥ 45°C, the trend was decreasing but insignificant. For temperature extreme ≤10°C, a significant decreasing trend was observed.

Keywords: Climate change; Mann-Kendall test; trend analysis.

1. INTRODUCTION

In our planet, climate is one of the most important key components. Rainfall, temperature are the main constituent of weather and climate. Climate is the statistical description of variability and mean of different weather parameters over a period of time ranging from month to thousands or millions of years [1]. Detection of climate change is the long term changes in the climate

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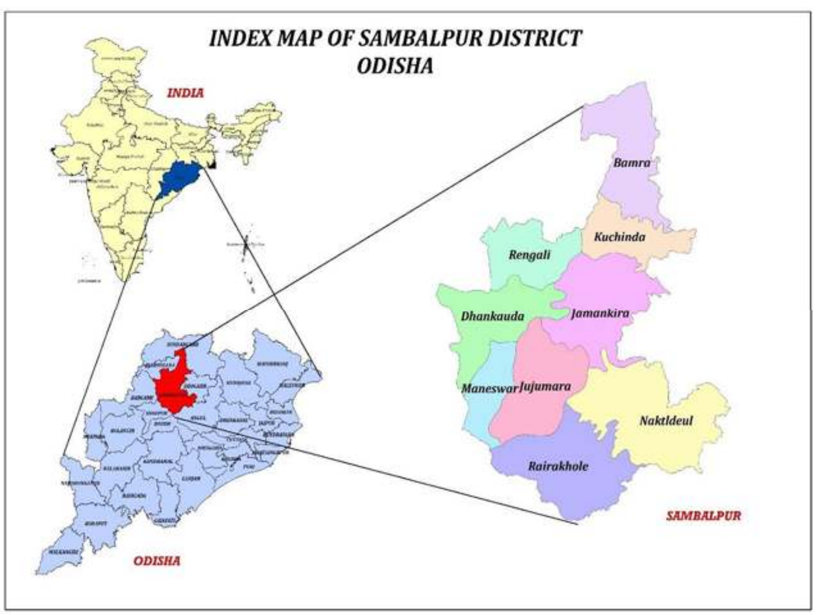
variables. Through extensions and improvements of various meteorological datasets and advance sophisticated data analysis, the past and recent climate change has gained sizable consideration across the globe [2]. The temperatures and rainfall [3] are the most important weather parameters, as these parameters determine agro-climatic condition of that particular region which influences all the agricultural and allied sectors [2,4]. Climate change has extensive impact on the agronomy, water resources, natural reserves and biodiversity [5]. The changes in temperature and rainfall are likely to influence the Indian agriculture. Variation in rainfall affect the soil moisture storage which ultimately relates to the growing degree days of cropping system. Similarly high or low temperature due to climate change in a region plays crucial role in shifting of cropping pattern of that particular area. Extreme weather patterns have resulted in unreasonable biotic and abiotic stress in agriculture sectors influencing the productivity of crop. In India 80-85% of rainfall is mainly contributed by Southwest monsoon and variation in the intensity, frequency and onset of southweast monsoon have a significant impact on agricultural production [6,7]. Trend analysis focuses on overall pattern of change over the time which help in temporal and spatial comparison for deriving the future projection. Climate change alter rainfall patterns and increases the frequency of extreme events like drought, heat wave cold wave, etc. States like Odisha and the coastal regions of Andhra Pradesh are experiencing the most vulnerable, and prolonged heat waves [8]. There is an significant increase in the trend of heat wave and severe heat wave in Odisha, Andhra Pradesh and West Madhya Pradesh [3]. A increased drought and heat wave has been projected in most places in India during twenty-first century [9]. Frequency of Higher daily maximum temperature, more intense and longer heat wave are increasing globally due to climate change. India is too facing the increased instances of heat waves with each passing year (IMD, 2022). Hence, the purpose of this study was to investigate the variability of the rainfall and temperature of 9 blocks of Sambalpur district of Odisha, India. Understanding the uncertainties associated with rainfall and temperature patterns will provide better knowledge for better management of agriculture, irrigation and other water-related activities in the selected area [10-16].

1.1 Study Area

Sambalpur is a district having nine blocks, situated in the western part of Odisha and comes under western central table land zone. Sambalpur district experiences the extreme climatic condition. Summers are hot and dry, winters are extremely cold and monsoons are wet and humid.



Map 1. Location map of study area

2. METHODOLOGY

The meteorological data (Rainfall and Temperature) were collected from the year 1990 to 2019 i.e. 30 years of time span. The rainfall data (mm), daily and month wise were collected from the Special Relief Commission (SRC) website, Odisha. The maximum and minimum temperature data in °C (Degree Celsius) were collected from NASA power from the year 1990 to 2019.

The daily rainfall series was converted to monthly, annual and seasonal data series. As the seasonal rainfall was contributing most part of annual rainfall hence only monsoon seasonal (seasonal) rainfall was calculated. The mean (μ), Standard Deviation (SD), and Coefficient of Variation (CV) of seasonal (monsoon) rainfall was calculated using following formulae:

$$\text{Mean } (\mu) = \frac{\text{Sum of all obsevations}}{\text{Number of obsevation}} \quad \text{(Eq. 1)}$$

$$\text{SD } (\sigma) = \sqrt{\frac{\Sigma(Xi-\bar{X})}{n-1}} \quad \text{(Eq. 2)}$$

Xi= The value in the data distribution
$\bar{X}$ = Sample mean
n=Total number of observations

$$\text{CV} = \frac{Standard\ deviation}{Mean} \times 100 \quad \text{(Eq. 3)}$$

Mean annual maximum and minimum temperature were calculated with standard deviation and coefficient of variation from daily temperature data, for 9 blocks from the year 1990 to 2019.This calculation provided the information regarding the temperature profile of all blocks of Sambalpur district.

Extreme temperature frequency was calculated by using daily Tmax and Tmin data separately. According to India Meteorological Department (IMD) Extreme temperature was taken as ≥40°C and ≥45°C for Tmax and ≤10°C for Tmin. Temperature frequency was calculated to know the pattern of extreme temperature over the years from 2001-2019 for the Sambalpur district.

Addinsoft's XLSTAT 2012 software was run to perform Mann-Kendall test. The output of the trend analysis was obtained in the form of p-value of test statistics which was tested against significance level 0.05 (α value) for both temperature and rainfall data for the nine blocks. In addition, to compare the results obtained from the Mann-Kendall test, linear trend lines are plotted for each block using Microsoft Excel 2016.

3. RESULTS AND DISCUSSION

3.1 Rainfall Variability

Table 1 explained that the Sambalpur district had received maximum amount of rainfall i.e. 30.43% of rainfall in August followed by 28.44% in July. Except Bamra, Jamankira and Kuchinda, all others block received the highest rainfall in August. Bamra, Jamankira and Kuchinda received highest amount of rainfall in July. The district had received the lowest amount of rainfall in February (0.46%) followed by March (0.47%). Jujumura, Kuchinda and Rengali block had received the lowest amount of rainfall in March. Dhankauda, Jamankira, Maneswar, Naktideul and Rairakhol had received lowest rainfall in February. Only Bamra block had received lowest amount of rainfall in January. Hence, the whole district received most of its rainfall during south-west monsoon or seasonal rainfall in August month which was highest in July month, one decade ago. The result indicates the possible shifting of late onset of monsoon in the district. Sambalpur district received most of its annual rainfall (85.4%) during the south-west monsoon followed by post-monsoon which had received 7.9 per cent, and 5.9 per cent in pre-monsoon season. Through Table 2 it was concluded that the mean seasonal rainfall of the district had been recorded as 1293 mm ± 368 mm. The spatial variability of mean seasonal rainfall had been recorded at each block. It was observed that Jujumura had received the highest seasonal rainfall of 1752 ± 603 mm. Jamankira block had received lowest seasonal rainfall i.e. 1151 ± 373 mm. As the Jujumura block is hilly region and forest covered area so there is possibility of enhanced rainfall in this block. From result Table 3 and Fig. 1 it was observed that Dhankauda, Naktideul and Rairakhol were showing the decreasing trend, where only in Rairakhol, it was significantly decreasing trend. All other blocks were showing the increasing trend, where Jamankira, Jujumura and Kuchinda were showing significantly increasing trend of annual seasonal rainfall. so there is a net increase in the rainfall pattern in Sambalpur district as most of the blocks are showing the positive trend and it was more visible in Jujumura block which was receiving maximum amount of rainfall as well as the significant positive trend. So topographical factor especially hilly terrain may be playing a

Table 1. Long term mean monthly rainfall (mm) of Sambalpur district (1990-2019)

Sl. No.	Block	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec	MAR
1	Bamra	5.54	8.29	7.09	16.68	32.66	228.95	403.67	363.54	225.54	43.85	12.46	14.71	1362
2	Dhankauda	11.84	5.26	10.51	10.84	26.82	221.33	410.15	470.10	242.84	53.43	7.62	14.49	1485
3	Jamankira	11.45	5.56	6.38	16.86	32.36	198.32	373.29	354.49	224.40	51.84	9.90	15.92	1300
4	Jujumura	11.68	8.25	6.86	12.57	44.77	256.53	554.71	590.38	350.47	73.80	14.29	15.73	1940
5	Kuchinda	8.37	9.79	5.89	8.58	25.55	197.46	382.30	365.89	215.57	53.13	10.87	17.36	1340
6	Maneswar	7.89	6.05	6.48	9.16	28.51	218.26	413.77	457.83	239.30	47.23	8.85	9.89	1453
7	Naktideul	10.16	4.71	5.04	14.60	35.70	201.67	366.69	384.34	202.14	66.72	8.35	10.10	1310
8	Rairakhol	9.03	3.39	7.23	11.44	30.34	191.83	400.17	428.14	237.11	65.25	10.91	8.69	1403
9	Rengali	7.79	9.59	6.74	11.89	34.17	214.85	401.09	423.81	228.41	53.61	12.09	13.87	1417
	District	**9.30**	**6.76**	**6.91**	**12.51**	**32.33**	**214.36**	**411.76**	**426.50**	**240.64**	**56.54**	**10.59**	**13.42**	

Table 2. Statistical characteristics of mean seasonal rainfall block wise

Sl. No.	Name of the Block	Mean seasonal rainfall (mm)	Standard deviation	Coefficient of variation (%)
1	Bamra	1222	312	25
2	Dhankauda	1344	403	30
3	Jamankira	1151	373	32
4	Jujumura	1752	603	34
5	Kuchinda	1161	356	30
6	Maneswar	1329	357	26
7	Naktideul	1155	261	22
8	Rairakhol	1257	364	29
9	Rengali	1268	285	22
	District	**1293**	**368**	**27**

Table 3. Statistical table for trend analysis of seasonal rainfall

Sl. No.	Name of the block	Kendall's Tau	p-value (two tailed test)	Alpha	Trend interpretation
1	Bamra	0.237	0.069 (NS)	0.05	Increase
2	Dhankauda	-0.246	0.059 (NS)	0.05	Decrease
3	Jamankira	0.269	0.038 (S)	0.05	Increase
4	Jujumura	0.264	0.042 (S)	0.05	Increase
5	Kuchinda	0.274	0.035 (S)	0.05	Increase
6	Maneswar	0.021	0.887 (NS)	0.05	Increase
7	Naktideul	-0.011	0.943 (NS)	0.05	Decrease
8	Rairakhol	-0.260	0.046 (S)	0.05	Decrease
9	Rengali	0.053	0.695 (NS)	0.05	Increase

Table 4. Statistical characteristics of maximum temperature (^{0}C) block wise

Sl. No.	Name of the Block	Mean maximum temperature (^{0}C)	Standard Deviation	Coefficient of variation (%)
1	Bamra	33.250	.562	1.9
2	Dhankauda	33.110	.500	1.5
3	Jamankira	33.290	.606	1.8
4	Jujumura	33.150	.591	1.7
5	Maneswar	33.420	.747	2.3
6	Kuchinda	33.180	.582	1.7
7	Naktideul	32.420	.754	2.9
8	Rairakhol	33.310	.623	1.8
9	Rengali	32.520	.598	1.1
	District	**33.060**	**.618**	**1.8**

Table 5. Statistical table for trend analysis of maximum temperature (^{0}C) block wise

Sl. No.	Name of the block	Kendall's Tau	p-value (Two tailed test)	Alpha	Trend interpretation
7	Bamra	0.306	0.018 (S)	0.05	Increase
2	Dhankauda	0.325	0.012 (S)	0.05	Increase
6	Jamankira	0.138	0.292(NS)	0.05	Increase
1	Jujumura	0.339	0.009 (S)	0.05	Increase
5	Kuchinda	-0.369	0.005 (S)	0.05	Decrease
4	Maneswar	-0.189	0.148 (NS)	0.05	Decrease
9	Naktideul	-0.170	0.193 (NS)	0.05	Decrease
8	Rairakhol	0.314	0.016 (S)	0.05	Increase
3	Rengali	0.306	0.018 (S)	0.05	Increase

Table 6. Statistical characteristics of minimum temperature (^{0}C) block wise

Sl. No.	Name of the Block	Mean minimum temperature (^{0}C)	Standard deviation	Coefficient of variation (%)
1	Bamra	19.710	.323	.016
2	Dhankauda	20.000	.556	.027
3	Jamankira	19.890	.501	.025
4	Jujumura	20.870	.602	.028
5	Kuchinda	20.250	.322	.015
6	Maneswar	19.730	.688	.034
7	Naktideul	20.530	.298	.014
8	Rairakhol	20.630	.317	.015
9	Rengali	19.560	.495	.025
	District	**20.130**	**.455**	**.022**

Table 7. Extreme (high and low) temperature of Sambalpur district

Sl. No.	Year	No of Days ≥ 40^{0}C	No of Days ≥ 45^{0}C	No of Days ≤ 10^{0}C
1	2001	38	4	67
2	2002	44	6	49
3	2003	63	16	53
4	2004	32	0	38
5	2005	47	5	26
6	2006	13	0	22
7	2007	35	1	17
8	2008	43	0	3
9	2009	78	15	16
10	2010	75	18	26
11	2011	21	0	6
12	2012	53	0	11
13	2013	54	11	17
14	2014	60	0	18
15	2015	31	7	19
16	2016	64	3	13
17	2017	66	1	7
18	2018	52	4	11
19	2019	55	6	15
	Mean	48	5	22

Table 8. Statistical table for trend analysis of temperature extreme

Sl. No.	Temperature extreme class	Kendall's Tau	p-value (Two tailed test)	Alpha	Trend interpretation
1	≥ 40^{0}C	0.240	0.164	0.05	Increase
2	≥ 45^{0}C	-0.006	0.972	0.05	Decrease
3	≤ 10^{0}C	-0.519	0.002	0.05	Decrease

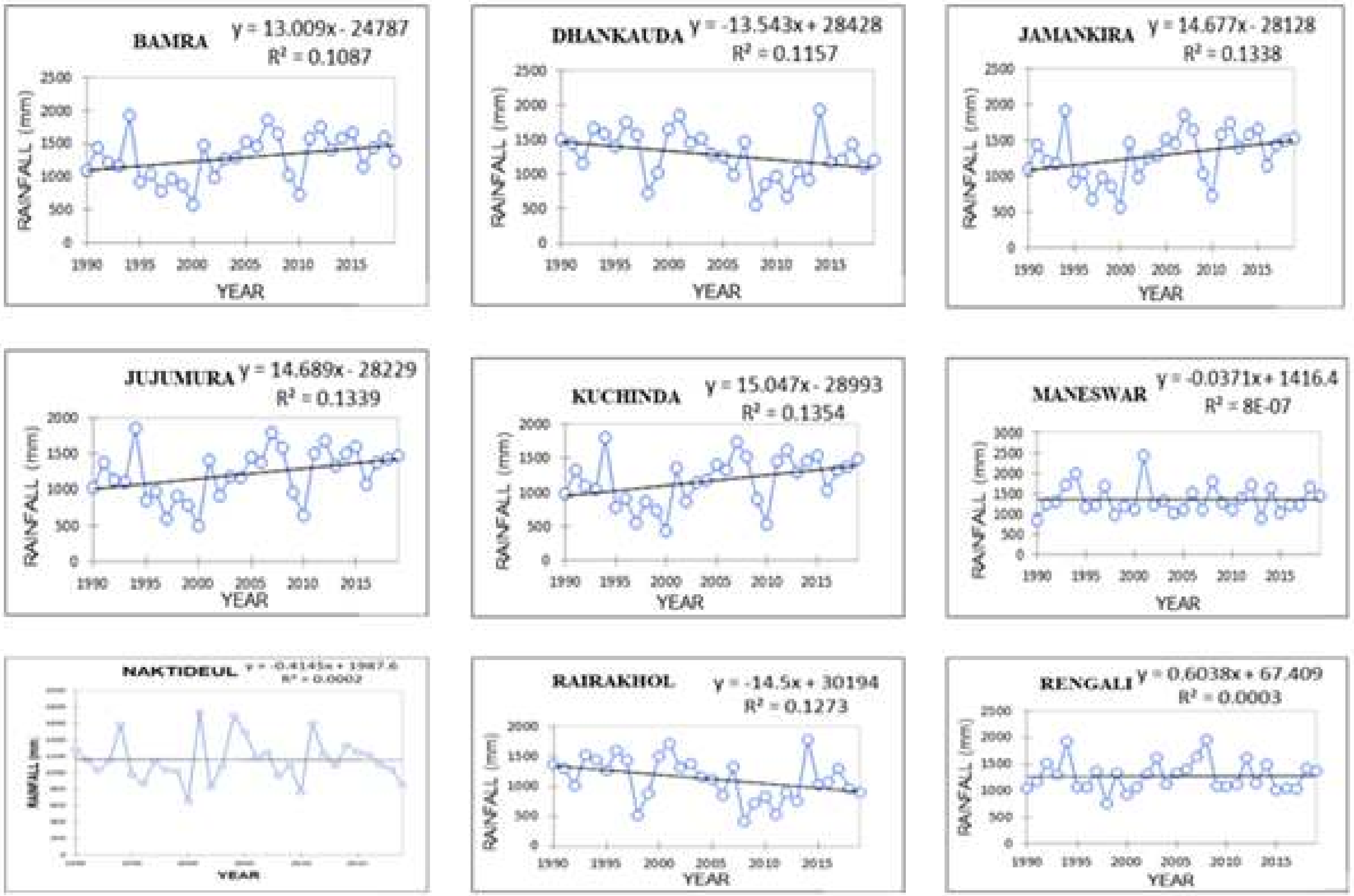


Fig. 1. Trend of seasonal rainfall in all the blocks of Sambalpur district

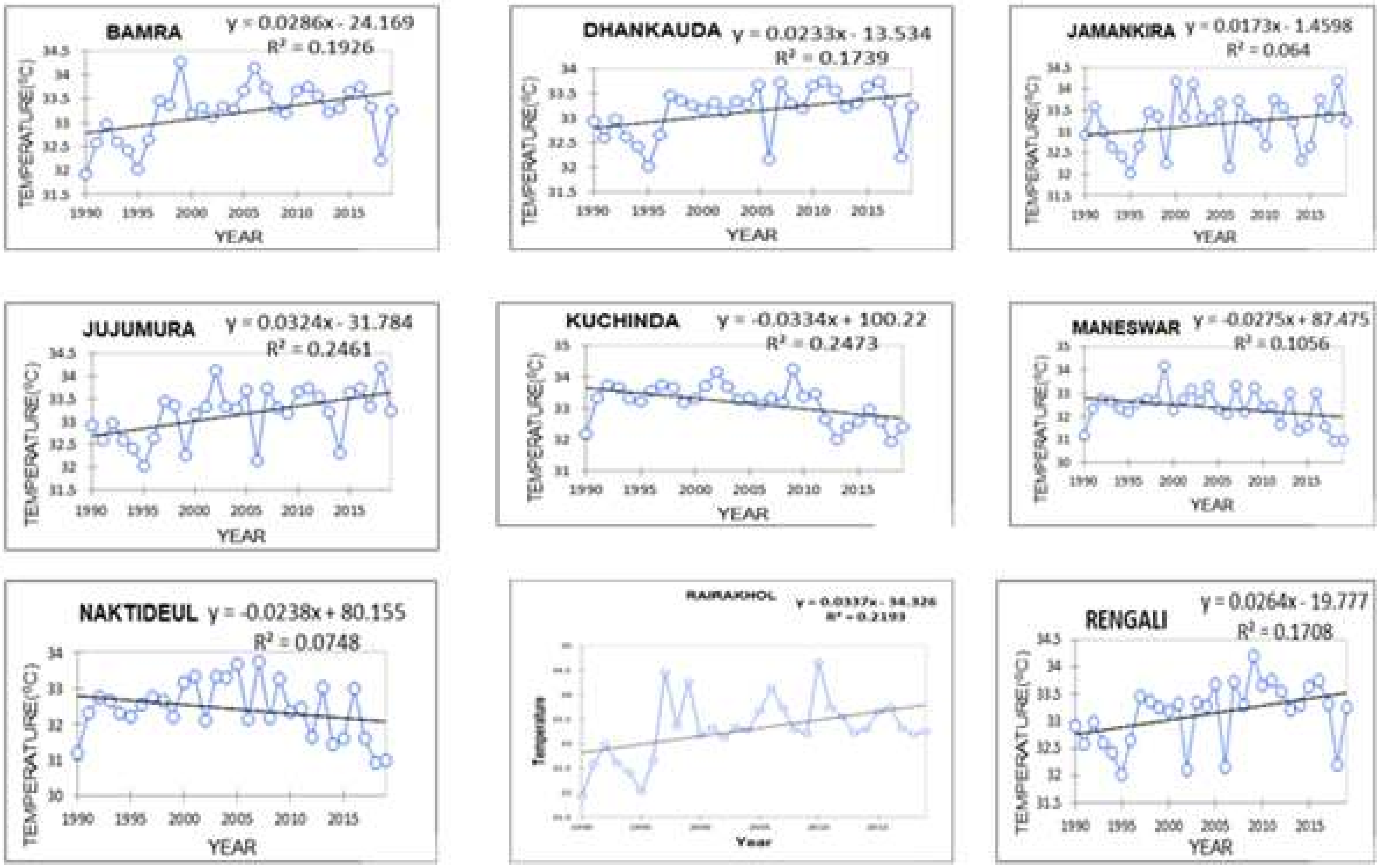


Fig. 2. Trend of maximum temperature in all the blocks of Sambalpur district

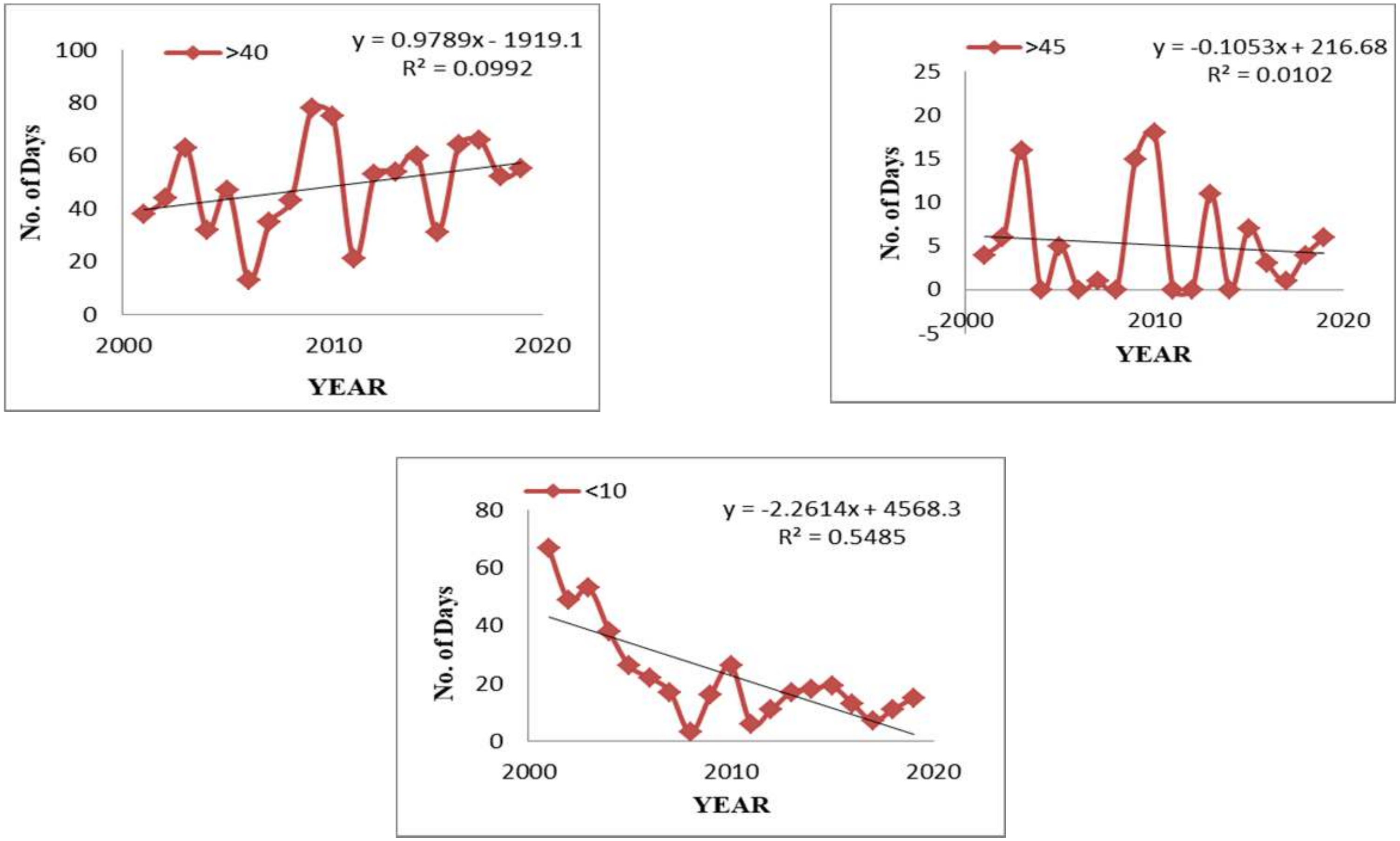


Fig. 3. Trend of extreme temperature in Sambalpur district

major role in Jujumura block but in others block it was obscure. A study conducted by Panda and Sahu,2019 in Kalahandi, Bolangir and Koraput district of Odisha, the similar kind of result was observed. So it was observed that most of the district in Westren part of the Odisha may be experiencing the high rainfall pattern due to possible climate change.

3.2 Temperature Variability

From Table 4 it was concluded that the mean maximum temperature of the district was 33.06°C ± 0.618 and CV of 1.8 %. The highest mean maximum temperature was observed in Maneswar block i.e. 33.42°C ± 0.747 with CV of 2.3% followed by Jamankira block which was 33.29°C ± 0.606 with CV of 1.8%. With 32.42°C the Naktideul block had experienced the lowest mean maximum temperature. From result Table 5 it was concluded that the Rengali block had experienced the lowest minimum temperature i.e. 19.56°C ± 0.495. The mean minimum temperature of the district was 20.13°C ± 0.455 along with CV of 2.2 per cent. From Table 6 and Fig. 2 it was concluded that Kuchinda, Maneswar, and Naktideul blocks were showing the decreasing trend of which, the trend in Kuchinda block was only significant. Other blocks were showing the significantly increasing trend except Jamankira block where the trend was not significant. From Table 7 It was observed that Sambalpur district had experienced a mean (2001-2019) of 48 days ≥40⁰C, a mean (2001-2019) of 5 days ≥45⁰C and a mean of 22 days ≤10⁰C. From the result it was observed that year 2009 (78 days ≥40⁰C and 15 days ≥45⁰C) and 2010 (75 days ≥40⁰C and 18 days ≥45⁰C) were the hottest year. It was also observed that the number of hot days had increased over year from 2001 to 2019. From the result table it was observed that year 2001 was the coldest year with number of days ≤10⁰C was 67 followed by 2003 i.e. 53. The Sambalpur district had experienced a mean (2001-2019) of 22 colder days with temperature ≤10⁰C. Over the years the number of days ≤10°C had decreased. Finally, it was observed that, in Sambalpur district the average number of hot days was 26 days higher than that of cold days. From Table 8 and Fig. 3, it was observed that for temperature extreme ≥ 40⁰C, the trend was increasing but insignificant. For temperature extreme ≥ 45⁰C, although trend was negative but the Kendall's tau value was very small i.e. -0.006 and was also insignificant. For temperature extreme ≤ 10⁰C, a significant decreasing trend was noticed. Maximum numbers of block showed higher maximum temperature and most of blocks experienced the increased minimum temperature. Increased frequency of heat wave (Temperature extreme ≥40⁰C and 45⁰C) and reduced frequency of cold wave (Temperature extreme≤10⁰C) indicating that there is an overall increase in temperature in Sambalpur district which might be due to the effect of climate change.

4. CONCLUSION

The time series analysis of long term climatic data of Sambalpur district claimed that six blocks out of nine blocks experienced increasing trend in rainfall but not significant, whereas maximum temperature in most of the blocks exhibited a significant increase over the years (1990- 2019) with the increasing frequency of hot days ≥40°C and decreasing frequency of cold days ≤10°C. Hence there is an overall increase in temperature in Sambalpur district from the year 1990 to 2019. It clearly indicates global warming. Changing climate brings a cascade of risks from physical impact on agroecosystem, agricultural production, and food chains to economic and social impacts on livelihood, income and trade, food security and nutrition (FAO 2016).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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