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Temporal variation in precipitation and temperature in Arunachal Pradesh, India

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सार – यह अध्ययन 1983 से 2021 तक अरुणाचल प्रदेश के लेपा राडा जिले में वर्षा और तापमान में अस्थायी बदलावों की जांच करता है। पैरामीट्रिक (रैखिक प्रतिगमन) और गैर-पैरामीट्रिक (मान-केंडल और सेन की ढलान) दोनों विधियों का उपयोग करके, महत्वपूर्ण जलवायु रुझानों की पहचान की गई। विश्लेषण से सर्दियों की बारिश में सांख्यिकीय रूप से महत्वपूर्ण गिरावट की प्रवृत्ति का पता चला, जिसमें रैखिक प्रतिगमन 2.809 मिमी/वर्ष की कमी दर्शाता है, जो महत्वपूर्ण मान-केंडल के जेड सांख्यिकी और सेन के ढलान अनुमानों द्वारा पुष्टि की जाती है। तापमान के रुझान ने सभी मौसमों में अधिकतम तापमान में उल्लेखनीय वृद्धि दिखाई (वसंत @ 0.109 डिग्री सेल्सियस/वर्ष; ग्रीष्म @0.103 डिग्री सेल्सियस/वर्ष; शरद ऋतु @0.113 डिग्री सेल्सियस/वर्ष और सर्दी @0.139 डिग्री सेल्सियस/वर्ष), इसी तरह, मैन-केंडल परीक्षण ने सभी मौसमों में महत्वपूर्ण Z मानों के साथ इन निष्कर्षों की पुष्टि की। इसके विपरीत, न्यूनतम तापमान में वसंत और सर्दियों के दौरान महत्वपूर्ण गिरावट देखी गई, जो समय के साथ ठंड में वृद्धि का संकेत देता है। ये रुझान क्षेत्र में कृषि और पर्यावरण नियोजन के लिए महत्वपूर्ण निहितार्थ रखते हैं। सर्दियों की बारिश में कमी और अधिकतम तापमान में वृद्धि फसल की पैदावार और जल संसाधनों पर प्रतिकूल प्रभाव डाल सकती है, जिससे अनुकूल कृषि पद्धतियों और कुशल जल प्रबंधन रणनीतियों की आवश्यकता पर बल मिलता है। इसके अतिरिक्त, सर्दियों और वसंत के दौरान ठंड में वृद्धि जलवायु-लचीली फसलों को विकसित करने और किसानों को मौसम की बदलती परिस्थितियों के लिए बेहतर तरीके से तैयार करने में मदद करने के लिए पूर्वानुमान प्रणालियों में सुधार के महत्व का सुझाव देती है।

ABSTRACT. This study examines the temporal variations in rainfall and temperature over the Lepa Rada district of Arunachal Pradesh from 1983 to 2021. Using both parametric (Linear Regression) and non-parametric (Mann-Kendall and Sen's slope) methods, significant climatic trends were identified. The analysis revealed a statistically significant declining trend in winter rainfall, with linear regression indicating a decrease of 2.809 mm/year, corroborated by significant Mann-Kendall's Z statistic and Sen's slope estimates. Temperature trends showed a significant increase in maximum temperatures across all seasons(spring@ 0.109 °C/year; summer @0.103 °C/year; autumn @0.113 °C/year and winter @0.139 °C/year), with annual rates of increase observed at 0.115°C/year ($p<0.01$) through linear regression. Similarly, the Mann-Kendall test confirmed these findings, with significant Z values across all seasons. In contrast, minimum temperatures showed a significant declining trend during spring and winter, suggesting increased coldness over time. These trends hold significant implications for agriculture and environmental planning in the region. The decline in winter rainfall and the rise in maximum temperatures could adversely affect crop yields and water resources, emphasizing the need for adaptive agricultural practices and efficient water management strategies. Additionally, the increase in coldness during winter and spring suggests the importance of developing climate-resilient crops and improving forecasting systems to help farmers better prepare for changing weather conditions.

Key words – Climate variability, Linear regression, Mann-Kendall test, Sen's slope.

1. Introduction

The indication of climate change, in a given place, is manifested through abnormal changes in climatic behaviour. Rainfall and temperature are the two major factors, which governs the ultimate climatic vulnerability profile of any given location. During recent times, researchers have reported abnormal changes in the climatic pattern over different parts of the world as reported by the Intergovernmental Panel on Climate Change (IPCC, 2007b). Globally, the average surface temperature indicated a linear warming pattern of 0.87 °C between 2006 and 2015, which is expected to rise by 1.5 °C during 2030-2052 (IPCC, 2018). According to National Oceanic and Atmospheric Administration (NOAA, 2020), the year 2019 was the warmest which experienced an elevated annual temperature 1.1 °C. The air temperatures did not increase equally over the globe (Rosenberg *et al.*, 2003). However, rainfall over the tropics is expected to rise by 0.2-0.3% every decade by the end of the twenty-first century (IPCC, 2007a).

The average annual rainfall in the North-Eastern Region (NER) of India is 2450 mm (Das *et al.*, 2010) and the region falls under low rainfall variability (8-15%). The Erratic nature of rainfall, its intensity and frequency often make crop planning a difficult task in rainfed areas. The region also faced a rainfall deficit in the past years. According to the India Meteorological Department (IMD) a high-pressure area over the region occurs when there is a low-pressure system over the Bay of Bengal and a typhoon also exists over the South China Sea. This was exactly the situation observed in 2006. In 2006, the anti-cyclonic system - that is high-pressure system over Eastern Tibet, was visible in the far west of its normal position, causing less rainfall in the NER of India. According to IMD records, the amount of rainfall received by the NER in 2006 monsoon season stands to be the scantiest in a period of 25 years, since 1982. Out of the seven North Eastern states, Assam and Meghalaya, with 32% rainfall deficit seems, to have suffered the most from rainfall deficit and high temperatures during the 2006 monsoon season while the remaining states experienced 25% rainfall deficit during the period (Das *et al.*, 2010). By the end of July 2009, most of the North Easternstates were affected by a drought like situation. Manipur, Nagaland and Meghalaya witnessed severe meteorological drought while other states have recorded moderate drought. Till 20th July, 2009, Manipur recorded 67% rainfall deficiency followed by Nagaland (63%), Meghalaya (56%), Assam (34%), Mizoram (32%), Tripura (31%) and Arunachal Pradesh (29%) (Times of India, 22 July, 2009). Analysis of long-term temperature data for the region points to a distinctly rising trend in surface air temperatures. The annual mean maximum temperatures in the region were rising at the rate of 0.11 °C per decade. The annual mean temperatures also increased at the rate of 0.04 °C per decade in the region (Das, 2004).

Recent studies have shed light on the changing climatic patterns in this region. Das *et al.* (2010) provided insights into the changing rainfall patterns, highlighting the need for a deeper understanding of precipitation trends. Mishra *et al.* (2020) analyzed the changing rainfall and temperature patterns over Northeast India, emphasizing the importance of studying both variables to comprehend regional climate dynamics. Patel, *et al.* (2020) further analyzed temperature variation and trends over Northeast India. Furthermore, Gadgil *et al*. (2007) discussed the role of clouds over the Indian Ocean in Indian summer monsoon droughts, indicating a significant influence of large-scale atmospheric circulation patterns on regional climate variability. Goswami *et al.* (2006) highlighted an increasing trend of extreme rain events in India, attributing it to a warming environment. Pandey and Pandey (2021) provided an analysis of rainfall trends and characteristics over Northeast India from 1983 to 2019, further enhancing our understanding of changing precipitation patterns in the region.

Understanding these changing climatic patterns is crucial for the development of effective adaptation and mitigation strategies. While climate change research is often conducted at a macro level, there is a growing need to narrow down the focus to the local level to comprehend its micro-level implications (Pielke *et al.*, 2002). Therefore, this study aims to analyze the temporal variation in rainfall, maximum temperature and minimum temperature during 1983-2021 in Lepa Rada district, located in Arunachal Pradesh.

The importance of this study lies in its focus on a specific district, Lepa Rada, located in Arunachal Pradesh, which was bifurcated from the Lower Siang District in 2018. This focused analysis aims to contribute to a more nuanced understanding of the local climate dynamics and help in devising region-specific adaptation and mitigation strategies. Additionally, by extending the analysis to 2021, this study provides up-to-date insights into the recent climatic trends in the region, thus filling a crucial gap in existing research.

2. Data and methodology

2.1. *Data used*

The study analyzed daily rainfall (mm), daily maximum temperature (°C) and daily minimum temperature (°C) recorded at the agro-meteorological observatory of ICAR Research Complex for NEH Region, Basar, Lepa Rada district, Arunachal Pradesh (Latitude: 27°59.701' N; Longitude: 94°42.227' E; Altitude: 725 meters above mean sea level). The agro-meteorological observatory operates manually, with a meteorological observer recording various weather parameters from different instruments at specified times of the day, following the criteria set by the India Meteorological Department (IMD). Daily rainfall is measured using a non-recording or manual rain gauge, and the highest and lowest temperatures are recorded using a maximum and minimum thermometer.

2.2. *Methodology applied*

To understand the various features of the weather data used in this study, descriptive statistical measures like mean, coefficient of variations, kurtosis and skewness were computed. The present study analyzed rainfall and temperature patterns on a monthly, seasonal, and annual basis. For the seasonal analysis, four distinct seasons were considered : spring (March to May), summer (June to August), autumn (September to November), and winter (December to February).

The patterns in the long period of meteorological data can be identified using a large range of experiments (Tabari *et al*., 2011). In this analysis, both parametric (linear regressions), and non-parametric (Mann Kendall and Sen's slope) methods were employed to identify patterns in temperature and rainfall. Being simple in calculations, parametric methods are often preferred (Mosmann *et al.*, 2004). The restriction of normal distribution in these parametric tests can be tackled by allowing transformations of the data set (Huth, 1999). However, non-parametric methods are distribution free and the power of these tests is equally comparable to the parametric one (Zhang *et al.*, 2008).

2.2.1. *Linear regression*

Simple linear regression is a widely used parametric approach for the detection of linear trends in time series. A simple linear regression of the form Y = aT+b, where 'Y' represents the weather variables, 'T' represents time and 'a' and 'b' represents slope and intercept respectively, was used for the current study. A positive slope indicates a rising trend, while a negative slope shows a declining trend. Regression analysis depends on the slope of the hypothesis test results in the magnitude, *i.e*., the rate of change (regression coefficient) (Hirsch *et al.*, 1991). The cumulative adjustment over the time series is achieved by multiplying the slope by the number of years. In this work, the patterns were found to be statistically relevant at $a < 0.05$ level using the Student's *t*-test.

2.2.2. *Mann-Kendall test*

The Mann-Kendall test is a non-parametric test and identifies the pattern in time series data. Instead of simple data comparison, this test compares the relative magnitude of the input data (Gilbert, 1987). Being a non-parametric test, its result does not stick to any distribution of the series. Mann (1945) first used this measure and Kendall (1975) eventually derived the statistical distribution of the test. The Mann-Kendall Test is used to test the null hypothesis that there is no trend. The test statistic, 'S' was calculated as:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}\left(x_j - x_i\right)$$

where,

$$\operatorname{sgn}\left(x_j - x_i\right) = \begin{cases} 1, & \text{if } x_j - x_i > 0 \\ 0, & \text{if } x_j - x_i > 0 \\ -1, & \text{if } x_j - x_i < 0 \end{cases}$$

'x_j' and 'x_i' are annual and seasonal values of climatic variables in '*j*' and '*I*' years, where $j > I$, '*n*' is the number of data points.

A positive value of '*S*' indicates an increasing trend and a negative value indicate a decreasing trend. The S-statistic is used for the number of data points less than 10. For the current analysis, since the data points were greater than 10, Z-statistic was calculated. However, to compute the Z-statistic, the value of the S-statistic and its variance are required. When $n > 10$, S-statistic follows a normal distribution with mean, $E(S) = 0$ and variance as given below:

$$\operatorname{Var}(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} (t_i - 1)(2t_i + 5)}{18}$$

where, '*m*' is the number of tied groups (where values of the weather values are same) and 't_i' is the number of data points in the i^{th} tied group.

Z - statistic was calculated as:

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{\operatorname{Var}(S)}}, & \text{if } S > 0 \\ 0, & \text{if } S = 0 \\ \dfrac{S+1}{\sqrt{\operatorname{Var}(S)}}, & \text{if } S < 0 \end{cases}$$

TABLE 1

Statistical information of monthly (a) rainfall, (b) maximum temperature, (c) minimum temperature of Lepa Rada district of Arunachal Pradesh during 1983-2021

Month	Mean	Highest	Lowest	CV (%)	Skewness	Excess-Kurtosis
Rainfall						
January	46.43	140.10	0.00	74.20	0.84	0.14
February	79.50	184.70	9.00	58.87	0.60	-0.41
March	106.29	231.20	4.50	45.05	0.41	0.11
April	153.58	313.88	42.70	36.24	0.36	0.43
May	236.76	460.70	70.00	35.94	0.38	0.11
June	451.41	709.60	100.70	28.02	-0.34	0.02
July	481.01	899.00	180.90	39.20	0.52	-0.47
August	333.44	728.50	53.40	53.62	0.48	-0.51
September	340.20	820.60	96.80	43.63	0.86	1.10
October	135.83	384.40	2.60	59.70	1.11	1.41
November	40.36	120.00	0.00	82.42	0.80	-0.53
December	25.86	88.83	0.00	85.86	0.93	0.45
Maximum temperature						
January	17.27	21.13	12.70	14.73	-0.32	-1.07
February	18.53	23.36	13.30	16.18	-0.41	-1.15
March	20.71	24.74	14.20	12.53	-0.49	-0.26
April	23.14	27.77	17.50	10.52	-0.25	-0.31
May	26.16	31.70	20.90	9.58	0.09	-0.25
June	27.69	35.60	23.50	8.41	0.79	1.70
July	28.48	37.00	24.40	9.29	0.87	1.49
August	29.18	38.00	24.10	9.33	0.77	1.25
September	28.10	37.30	23.30	10.60	0.48	0.54
October	26.37	32.40	20.50	9.92	0.08	-0.30
November	23.31	37.00	16.20	15.00	1.25	4.57
December	19.31	26.50	14.10	15.28	-0.11	-0.30
Minimum temperature						
January	7.43	12.00	5.36	21.15	0.96	0.38
February	9.46	14.60	5.98	18.50	0.79	1.15
March	12.37	16.50	8.20	14.77	0.07	-0.21
April	15.33	20.30	7.76	15.33	-0.82	1.64
May	18.67	24.10	12.19	12.46	0.03	0.42
June	21.15	26.20	14.94	9.45	-0.35	1.27
July	22.27	31.00	19.50	10.06	1.66	3.98
August	21.91	25.40	17.80	8.65	0.22	-0.82
September	21.00	27.50	17.50	10.52	0.84	0.37
October	18.13	29.70	13.67	14.66	2.15	7.59
November	12.44	18.90	8.84	18.41	1.06	0.93
December	8.90	12.75	6.00	21.08	0.54	-0.66

The significance of Z-statistic will reject the null hypothesis of no trend, which means that a pattern is present throughout the data set and can be either positive or negative. A positive Z-value indicates an upward or increasing trend while a negative value indicate a downward or negative trend.

2.2.3. *Sen's slope estimator*

The Mann-Kendall test shows the presence of a trend or pattern, However, the magnitude of the pattern can be estimated by Sen's estimator (Sen, 1968). Sen's non-parametric method is used to measure the true slope of the current trend to compute the rate of change each year. However, linearity in the pattern of the time series is the main restriction of the Sen's estimator. The Sen's estimator is computed as :

$$F(t) = Qt + B \quad (1)$$

Here, 'Q' is the slope, 't' is the time, and 'B' is a constant. To get the slope, 'Q' is estimated by following Eqn. (1) and the slopes of the time series data are calculated by using Eqn. (2):

$$Q_i = \frac{x_j - x_k}{j - k} \quad (2)$$

Here, 'x_j' and 'x_k' are the data values in years 'j' and 'k', $j > k$. If there are 'n' values of 'x_k' in the time series, one gets as many as $N = n\,(n-1)/2$ slope estimates 'Q_j'.

Sen's estimator of the slope is the median of these N values of Q_i. The N values of Q_i are ranked from the smallest to largest, and Sen's estimator is estimated as per Eqn. (3).

$$Q = Q_{(N+1)/2} \text{ if } N \text{ is odd}$$

$$Q = \tfrac{1}{2}\,(Q_{N/2} + Q_{(N+1)/2}) \text{ if } N \text{ is even} \quad (3)$$

The either-sided confidence interval of the slope estimation can be obtained by a non-parametric technique considering normal distribution. Sen's slope estimator can accurately be used for a sample size as small as 10 unless there are several relations. A positive Q_i value indicates an upward trend, while a negative value determines the downward trend in the time sequence.

3. Results and discussion

The statistical information on monthly rainfall, maximum and minimum temperature of Lepa Rada during 1983-2021 is presented in Table 1. The average monthly rainfall was highest during the month of July (481.01 mm) which gradually decreased in the subsequent months and was lowest in December (25.86 mm). During the study period, the highest monthly rainfall was observed in July (899.00 mm) in the year 1985 and the lowest zero rainfall month was experienced in January (2010), November (2004) and December (2002, 2005, 2007 and 2008). The study also showed high variation in monthly rainfall which was indicated by high CV of monthly rainfall ranging between 28.02% and 85.86%. October having high positive skewness (1.11) indicated that the rainfall during this month tended to remain below average. Furthermore, during autumn (September, October and November) and winter (December, January and February) there was moderate positive skewness which implied that monthly rainfall during these months remained below average.

The mean monthly maximum temperature was highest during August (29.18 °C) and was recorded to be lowest during January (17.27 °C) followed by February (18.53 °C). From 1983-2021, the highest maximum monthly temperature of 38.00 °C was observed in the month of August during 2006, while the lowest maximum monthly temperature of 12.70 °C (January) was experienced in 1989. A high positive skewness of 1.25 was observed in the month of November and moderate positive skewness between 0.77 and 0.87 was experienced during June, July and August, indicating that the monthly maximum temperature during these months tend to be below average. A high positive kurtosis of 4.75 was observed in the month of November, signifying the heavy-tailed distribution and presence of an outlier. The high positive kurtosis in November (Table 1) could be due to the temperature spiking to 37 °C in 2007.

The mean monthly minimum temperature in Arunachal Pradesh ranged between 22.27 °C (July) and 7.43 °C (January). During the study period, the highest minimum monthly temperature of 31.00 °C was observed in the month of July during 2006, while the lowest minimum monthly temperature of 5.36 °C (January) was experienced in 1989. The inter-annual variation in monthly minimum temperature was high during the study period. High positive skewness of more than 1 was observed in the months of July, October and November and moderate positive skewness between 0.54 and 0.96 was experienced between January, February, September and December, indicating that the monthly minimum temperature during these months tend to be below average. The month April observed moderate negative skewness, reflecting that the minimum temperature in this month remained above average. High positive kurtosis of 7.59 and 3.98 were witnessed in the months of October and July, respectively, signifying the heavy-tailed

TABLE 2

Statistical information of seasonal (a) rainfall, (b) maximum temperature, (c) minimum temperature of Lepa Rada district of Arunachal Pradesh during 1983-2021

Season	Mean	Highest	Lowest	CV
Rainfall (mm)				
Spring	488.85	803.60	266.50	24.06
Summer	1239.42	2017.60	648.90	23.70
Autumn	513.02	1056.90	146.40	34.80
Winter	151.22	286.10	44.00	43.96
Annual	2392.50	3053.90	1603.15	15.27
Maximum temperature (°C)				
Spring	23.79	29.83	19.03	10.52
Summer	28.77	35.40	24.63	8.80
Autumn	26.25	33.73	21.43	10.58
Winter	18.74	23.90	13.90	13.67
Annual	24.39	29.56	19.98	9.82
Minimum temperature (°C)				
Spring	15.38	19.33	9.97	13.28
Summer	22.06	26.77	18.57	8.92
Autumn	17.23	25.17	14.19	13.04
Winter	8.42	12.73	3.80	18.72
Annual	15.77	19.08	12.72	9.66

distribution and presence of outliers. During October 2003 and 2007, the mean minimum temperature went up to 21.7 ºC and 29.7 ºC, respectively, which were much higher than the mean minimum temperature of the month (18.13 ºC). Again, during July 1983, 1997 and 2009, the mean minimum temperature had risen up to 26 ºC, 25.30 °C and 25.11 °C, respectively, from mean minimum temperature of 22.27 °C, resulting in high kurtosis (Table 1).

3.1. *Seasonal rainfall and temperature pattern during 1983-2021*

The analysis of rainfall, maximum temperature, and minimum temperature in the Lepa Rada district of Arunachal Pradesh from 1983 to 2021 (Table 2) reveals distinct seasonal and annual patterns. The average spring rainfall was 488.85 mm with moderate variability (CV = 24.06%), while summer exhibited the highest average rainfall of 1239.42 mm with consistent patterns (CV = 23.70%). Autumn rainfall showed greater variability with an average rainfall of 513.02 mm (CV = 34.80%) and winter had the lowest average rainfall at 151.22 mm, marked by the highest variability (CV = 43.96%). Annually, the average rainfall was 2392.50 mm, reflecting relatively stable conditions (CV = 15.27%). Maximum temperatures varied modestly across seasons, with spring maximum temperature of 23.79 °C (CV = 10.52%) and summer showing the highest average maximum temperature of 28.77 °C with the least variability (CV = 8.80%). Autumn and winter recorded average maximum temperatures of 26.25 °C (CV = 10.58%) and 18.74 °C (CV = 13.67%), respectively. Annually, the average maximum temperature was 24.39 °C with stable variation (CV = 9.82%). Minimum temperatures also displayed seasonal trends, with spring at 15.38 °C (CV = 13.28%) and summer having the highest average minimum temperature at 22.06 °C with the lowest variability (CV = 8.92%). Autumn and winter had average minimum temperatures of 17.23 °C (CV = 13.04%) and 8.42 °C (CV = 18.72%), respectively, while annual minimum temperatures were stable with an average of 15.77 °C (CV = 9.66%). These findings highlight the significant seasonal and annual variations in climate parameters, with

TABLE 3

Test for normality

Test	Rainfall		Maximum temperature		Minimum temperature	
	Statistic	p-value	Statistic	p-value	Statistic	p-value
Doornik-Hansen test	2.575	0.276	2.143	0.342	2.628	0.268
Shapiro-Wilk W test	0.948	0.068	0.961	0.193	0.955	0.124
Jarque-Bera test	1.829	0.401	1.812	0.403	1.778	0.140
Interpretation	Normal		Normal		Normal	

TABLE 4

Trend in rainfall and temperature using linear regression, Mann-Kendall and Sen's slope estimates

Variables		Spring	Summer	Autumn	Winter	Annual
Rainfall	Linear coefficient	2.620	-0.668	-0.817	-2.809***	-1.675
	Mann-Kendall's Z statistic	1.500	-0.190	-1.450	-2.830**	-0.730
	Sen's slope estimate	2.923	-0.691	-3.790	-2.567	-2.934
Maximum temperature	Linear coefficient	0.109***	0.103***	0.113***	0.139***	0.115***
	Mann-Kendall's Z statistic	3.530***	3.350***	2.890**	3.870***	3.460***
	Sen's slope estimate	0.107	0.105	0.109	0.130	0.114
Minimum temperature	Linear coefficient	-0.050*	-0.023	-0.014	-0.038*	-0.033
	Mann-Kendall's Z statistic	-1.570	-0.650	-0.530	-2.070*	-1.520
	Sen's slope estimate	-0.040	-0.021	-0.013	-0.040	-0.034

*,**&*** indicate level of significance at 10%, 5% and 1% respectively

implications for agricultural and environmental planning in the region.

The results indicate that summer experiences the highest rainfall and temperatures, with the most consistent patterns in both maximum and minimum temperatures, as evidenced by the lowest CVs. Winter, on the other hand, shows the lowest rainfall and the greatest variability in both maximum and minimum temperatures, suggesting a higher degree of climatic instability during this season. These variations in rainfall and temperature across different seasons can have substantial implications for agricultural practices and water resource management in the region. The high variability in winter conditions, particularly in rainfall and minimum temperatures, may pose challenges for crop planning and require the development of adaptive strategies to mitigate the impacts of climatic fluctuations.

3.2. *Analysis of trend in weather variables*

The datasets were tested for normality using the Doornik-Hansen test, Shapiro-Wilk W test and the Jarque-Bera test. The tests were subject to the null hypothesis that the datasets were normally distributed. The results are presented in Table 3, which showed non - significant

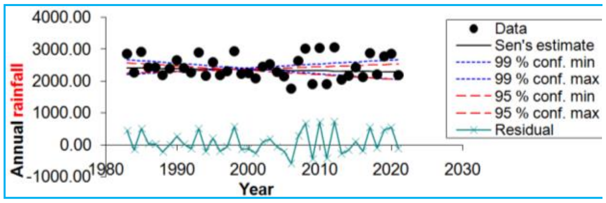

Fig. 1. Trend in annual rainfall during 1983-2021

statistic values for all the three weather variables. Thus, all the three weather variables were normally distributed and are eligible to be treated with linear regression.

3.2.1. *Temporal analysis of trend in rainfall during 1983-2021*

The linear regression model and Mann-Kendall & Sen's slope estimates revealed significant ($p<0.01$ and $p<0.05$, respectively) declining trend in winter rainfall at the pace of -2.809 mm/year and -2.567 mm/year respectively (Table 4). Similarly, Patle and Libang (2014) reported a significant decreasing trend in winter rainfall in East Siang, Upper Siang and lower Dibang valley of Arunachal Pradesh at the pace of -3.01 mm/year, -3.32 mm/year and -3.95 mm/year respectively during 1971-2007. Rainfall during post monsoon and winter season plays a significant role in crop intensification, particularly in rainfed agriculture of North-east India (Choudhury *et al.*, 2012). Thus, the significant decline in winter rainfall is a cause of concern for the farmers of the state in the cultivation of winter season crops. Declining trends in rainfall were also observed during summer, autumn and annual except during spring (1983-2019) in Arunachal Pradesh, although they were statistically insignificant (Table 4). Similar observation was experienced during 1951-2007 when there was a decreasing trend in summer monsoon rainfall in Arunachal Pradesh (Sreekala *et al.*, 2014). Saikia *et al.*, 2013 also reported a reduced amount of seasonal rainfall in Arunachal Pradesh at the rate of 14.8% during 1991-2007 from the baseline period of 1951-1990. The decreasing trend in seasonal rainfall, especially the summer, monsoon rainfall could be the after effect of decreasing trend in tropical easterly jet stream (Sreekala *et al.*, 2014). Patle and Libang (2014) revealed a significant decreasing trend in annual rainfall during 1971-2007 in East Siang, Upper Siang and Lower Dibang valley districts. The trend in annual rainfall of the study area is shown in Fig. 1. West Siang district experienced a decreasing trend in annual rainfall as well during the same study period, but it was statistically insignificant, which was in the same line with the finding of the present study. Bhagawati *et al.*, 2017 also reported no significant change in annual and seasonal rainfall but the number of rainy days declined by 11 per cent in Arunachal Pradesh. There was significant ($p<0.01$) reduction in the number of rainy days at Tirap, Changlang, Lower Dibang valley districts of Arunachal Pradesh during 1991-2007 compared to 1951-1990 (Saikia *et al.*, 2013).

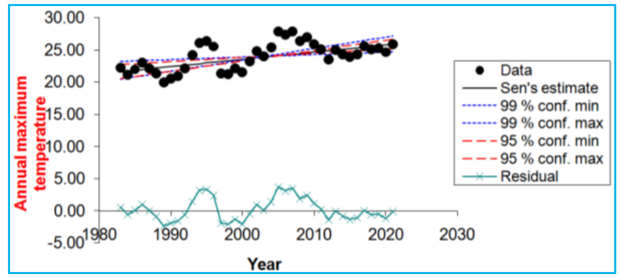

Fig. 2. Trend in maximum temperature during 1983-2021

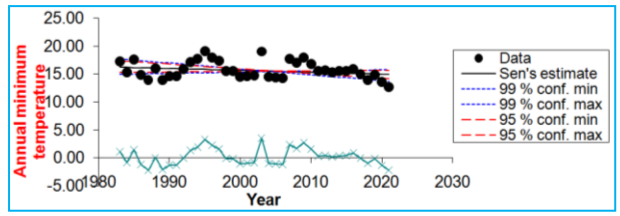

Fig. 3. Trend in minimum temperature during 1983-2021

3.2.2. *Temporal analysis of trend in maximum temperature during 1983-2021*

Analysis of seasonal and annual values of maximum temperature during 1983-2021 using linear regression and the Mann-Kendall test and Sen's estimator (Table 4 and Fig. 2) indicated a substantial rise in mean annual maximum temperature ($p<0.01$). Both the analyses revealed a rise in annual mean maximum temperature at the pace of 0.115 °C/year and 0.114 °C/year, respectively. The linear coefficients of maximum temperature showed a significant rise in spring, summer, autumn and winter ($p<0.01$) at the pace of 0.109 °C/year, 0.103 °C/year, 0.113 °C/year and 0.139 °C/year, respectively (Table 4). Similarly, Laskar *et al.*, (2014) reported a significant increasing trend in maximum temperature during winter and post-monsoon season during 1958-2012. The Eastern Himalayan region, especially Arunachal Pradesh, experienced widespread warming at the rate of 0.01 to 0.04 °C per year (Sharma *et al.*, 2009). According to the PRECIS(Providing Regional Climates for Impact Studies)regional model, the maximum temperature is projected to increase at the pace of 2.2 °C to 2.8 °C during the 2030s and towards 2080s, the increase in maximum temperature will be at the rate of 3.4 °C to 5 °C (SAPCC, 2011).

3.2.3. *Temporal analysis of trend in minimum temperature during 1983-2021*

Analysis of seasonal and annual minimum temperatures showed significant ($p<0.1$) declining trend in mean minimum temperature during spring and winter season, indicating that the coldness during these seasons increased over time (Table 4 and Fig. 3).

The decline in minimum temperature was at the pace of 0.050 °C/year ($p<0.1$) and 0.038 °C/year($p<0.1$), during the spring and winter season, respectively (Table 4). On the contrary, Laskar *et al.*, (2014) reported a significant increasing trend in minimum temperature at Pasighat, Arunachal Pradesh during 1958-2012.

4. Conclusions

The study conducted on the temporal variation in minimum temperature, maximum temperature, and precipitation in Lepa Rada district, Arunachal Pradesh, from 1983 to 2021, has revealed significant trends that hold critical implications for agriculture and water resource management in the region. The analysis indicates a significant decline in winter rainfall while maximum temperature increase significantly across all seasons, with the annual mean maximum temperature rising at a pace of 0.115 °C/year. Conversely, the minimum temperature showed a declining trend during the spring and winter seasons, suggesting an intensification of cold conditions during these periods.

The declining winter rainfall and rising maximum temperatures pose challenges for rainfed agriculture, particularly in the cultivation of winter crops. The increased temperatures could elevate evapotranspiration rates, further straining water resources, which may necessitate the adoption of water-efficient practices and improved irrigation infrastructure. While the study provides valuable insights into the climatic trends in Lepa Rada district, it is limited by its focus on a single district and the reliance on historical data. Future research should expand the geographical scope to include other regions of Arunachal Pradesh and employ more advanced climate models to project future climatic scenarios. Additionally, investigating the socio-economic impacts of these climatic trends on local communities could provide a more comprehensive understanding of the region's vulnerability to climate change.

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Dr. Nivetina Laitonjam: Analysis and preparation of manuscript.
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Dr. Pampi Paul: Reviewed of manuscript.
Sh. Kamni P. Biam: Assist in statistical analysis.
Sh. C. Gowda: Assist in statistical analysis.
Dr. Anjoo Yumnam: Assisted in analysis and development of methodology.
H. Dkhar: Assist in data collection and handling of software.
Dr. V. K. Mishra: Provided overall guidance and supervision throughout the preparation of the manuscript.

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