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Temporal Analysis of Rainfall and Temperature of Ranchi, Jharkhand for Period 1975-2050

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Abstract

The rainfall and temperature pattern of the study area Ranchi is analyzed for the period 1975-2023, and it is observed that the rainfall has an increasing trend for Annual, Monsoon, June, July, August, September, and October while temperature has an increasing trend for August only. The correlation between rainfall and average temperature emphasizes a negative correlation for annual, summer, March, May, and June at a 99 % confidence level while for July, September, and December, the correlation is negative at a 95 % confidence level. ARIMA(0,1,1) is chosen to be the most accurate model for the forecasting of rainfall and temperature for the period 2024-2050. Trend analysis of forecasted rainfall emphasizes an increasing trend for summer, monsoon, post-monsoon, and annual rainfall, whereas a negative trend is observed for winter rainfall. Trend analysis of forecasted temperature emphasizes an increasing trend for Monsoon while Annual and the rest of other seasons have negative trends.

Keywords: ARIMA modeling; Shift point detection; Rainfall forecasting; Temperature forecasting.

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1. Introduction

The Rainfall of India is heavily dependent upon the southwest monsoon, which runs from mid-July to mid-September. Monsoon rainfall in India contributes nearly 75 % rainfall to the annual rainfall. However, there is a large variation in the temporal rainfall. According to the fifth climate assessment report of the Intergovernmental Panel on Climate Change, the average worldwide combined land and ocean surface temperature rose by 0.85 °C between 1880 and 2012 [1]. A warmer climate is probably going to result in more heavy rainfall, which will probably come from fewer but stronger occurrences. The trend of seasonal rainfall of all sub-divisions throughout India was analyzed, and a substantial decline in tendency was discovered over three sub-divisions: Jharkhand, Chhattisgarh, and Kerala [2]. A significant downward trend was observed in annual, monsoon, and winter rainfall for the period 1901-2002 [3]. Pre-monsoonal rainfall distribution over Ranchi district was disturbed in the period 2000-2020 [4]. The seasonal Rainfall over Jharkhand

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has a decreasing trend for the period 1986-2018, and the average annual maximum and minimum temperatures are also increasing at a rate of 0.58 ºC and 0.46 ºC per decade, respectively [5]. Mann Kendall-Sneyers test can be applied to data sets for change point detection [6]. The changing pattern of rainfall and temperature has gathered eyes from around the world, and researchers around the globe are working on forecasting these events to understand the upcoming patterns and variability. Several methods, such as interpolation, Holt-Winter exponential smoothing, ARIMA, etc., can forecast rainfall and temperature. Ranchi's rainfall was forecasted for 2023-2030 using the Holt-Winter exponential smoothing method [7]. The trend of future rainfall in Chattogram, Bangladesh, projected by ARIMA using the historical rainfall data of the period 1970-2021, was analyzed, and it was reported that rainfall during the monsoon and December months would rise [8]. The trend of future weekly rainfall predicted by ARIMA modeling indicated a declining tendency in Iraq's semi-arid Sinjar area [9].

In this paper, historical rainfall and the average temperature have been analyzed for trend, variability, and correlation for 1975-2023, and then, the ARIMA model is used to forecast the future rainfall and average temperature for 2024-2050. The forecasted rainfall and average temperature are further analyzed to determine trends. For regional planning, studying temperature and precipitation at the global or continental scale is not particularly helpful [10,11]; hence, this temporal study of historical and future rainfall and temperature will help understand the changing pattern of rainfall and temperature at a regional scale. These findings can be utilized by government or private agencies to make plans to mitigate the impact of any extreme hydrological events, enhance crop yield, and plan water management.

2. Description of Study Area

Ranchi is the capital of the state of Jharkhand in India. It is located on the southern part of the Chota Nagpur plateau of eastern India, at 21°58` to 25º18` N latitude and 83°22` to 87°57` E longitude. Ranchi's climate is humid subtropical and receives unique convectional rainfall during summer (March-June). Ranchi receives good annual rainfall; approximately 80 % of rainfall is received during the southwest monsoon season from June to September [12]. The location map of Ranchi is displayed in Fig. 1.

3. Material and Methods

The daily rainfall and average temperature data of study area Ranchi for the period 1975-2023 are obtained from the website of the National Centre for Environmental Information (https://www.ncdc.noaa.gov/cdo-web/datatools/findstation). Monthly, seasonal, and annual data are calculated from daily data series. The statistical descriptions such as mean, standard deviation, and coefficient of variation are calculated for monthly, seasonal, and annual data. The rainfall data are further categorized into deficit and excess rainfall according to rainfall deviation from its long-term mean. Let 'm' be the long-term mean and 'd' be the long-term standard deviation of rainfall. Then rainfall in year 'YY' is categorized as

(1) deficit if Rainfall in YY < m - d

(2) Normal if m - d≤ Rainfall in YY ≤ m + d

(3) Excess if rainfall in YY> m + d.

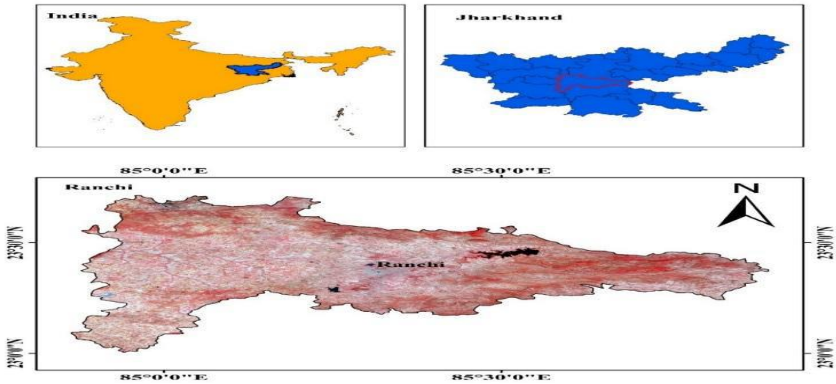

Fig. 1. Location map of Ranchi, Jharkhand.

Trend rainfall and average temperature analysis are done using Mann-Kendall [13] and Sen's slope method [14]. The shift point for the trend is analyzed using the Mann-Kendall-Sneyers sequential test [15]. The correlation analysis of rainfall and average temperature is done using Pearson's correlation test. Rainfall and average temperature forecasting from 2024 to 2050 are done using the ARIMA model. ARIMA model requires data to be stationary, and hence Augmented Dicky Fuller unit root tests are applied to the data set to know whether data is stationary or non-stationary.

3.1. *Mann-Kendall test*

It is a non-parametric test used to find trends in the data set. It is very useful as it does not require data to be normally distributed.
Let $x_1, x_2, x_3, \dots, x_n$ be the data set of length n. The indicator function Sgn$(x_i - x_j)$ is given as follows:

$$\text{Sgn}(x_i - x_j) = \begin{cases} 1, & x_i - x_j > 0 \\ 0, & x_i - x_j = 0 \\ -1, & x_i - x_j < 0 \end{cases}$$

The mean S and variance Var(S) of Sgn$(x_i - x_j)$are given as follows:

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

$$\text{Var}(S) = \frac{[n(n-1)(2n+5) - \sum_t t(t-1)(2t+5)]}{18}$$

Where t is the extent of any given tie.
The Z statistics for the MK test is given by

$$\mathbf{Z}=\begin{cases} \frac{S-1}{\sqrt{Var(S)}} & if\ S>0 \\ 0 & if\ S=0 \\ \frac{S+1}{\sqrt{Var(S)}} & if\ S<0 \end{cases}$$

The value of Z>0 represents a monotonic upward trend in the data series, whereas Z<0 represents a monotonic downward trend.

3.2. *Sen's Slope method*

It is a non-parametric test that is highly efficient in finding linear trends in univariate data series. This can be applied to a data set having missing values and outliers in the data series. The Sen's estimator β of slope is calculated as follows:

$$\beta = \text{Median}\left(\frac{x_j - x_i}{j-i}\right)$$

Where x_j and x_i are the data values at time j and i (j>i) respectively.
β>0 indicates an upward trend, whereas β<0 indicates a downward trend in the data series.

3.3. *Mann-Kendall-Sneyers test*

It is used in the detection of change points in significant trends. A progressive series and a retrograde series are created for this test. If the two series cross and diverge beyond a certain threshold value, then there is a statistically significant trend. The point at which they intersect indicates the approximate year when the trend begins. Let X=$\{x_1, x_2, x_3, \ldots, x_n\}$ be the total number of elements x_j preceding x_i (j<i) where $x_j < x_i$. The test statistic S_k derives the cumulative m_i for each year

$$S_k = \sum_{i=1}^{k} m_i \ \ (k = 1,2,3, \ldots, n)$$

The mean of S_k is given by

$$E(S_k) = \frac{k(k-1)}{4}$$

And the variance of S_k is given by

$$VAR(S_k) = \frac{k(k-1)(2k-5)}{72}$$

Now, the forward sequence $U_t and\ the\ backward\ sequence\ U'_t$ based on three variables $(S_k, E(S_k), VAR(S_k))$ is derived as follows:

$$U_t = \frac{S_k - E(S_k)}{\sqrt{VAR(S_k)}}$$

Now reverse the time series sequence X and call it Y. An intermediate sequence. Z_t is then calculated using data sequence Y. Now, in terms of sequence Z_t is reversed, and a negative sign is added to the reversed values. Thus, the newly obtained sequence is called U'_t.

3.4. *Pearson's correlation test*

It is a bivariate correlation test that measures the linear correlation between two data sets. It is the ratio between the covariance of two variables and the product of their standard deviation. Pearson correlation between two data points X and Y is given by:

$$\text{Correlation (X ,Y)} = \frac{Cov(X,Y)}{\sigma_X \times \sigma_Y}$$

Where Cov(X ,Y) is covariance of X and Y and is given by

$$\text{Cov(X ,Y)} = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})$$

Where $\bar{x}$ and $\bar{y}$ are mean of data set X and Y, respectively and n is the sample size.
And σ_X and σ_Y are standard deviations of X and Y, respectively.
The Pearson Correlation is the actual correlation value that denotes magnitude and direction, and the Sig. (2-tailed) is the *p*-value that is interpreted to check the significance of correlation. If the *p*-value is less than 0.05, then the correlation is statistically significant between the two data sets, and if the *p*-value is more than 0.05, then the correlation is not a statistically significant association between the two data sets [16].

3.5. *Augmented Dickey-Fuller Unit Root test*

The unit root test is used to check the stationarity of the data set. When a data set has no unit root means that the data set is stationary.
The unit root test in the time series y_t, the Dickey-Fuller equation is given by

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \sum_{i=1}^{p-1} \delta_i \Delta y_{t-i} + \varepsilon_t$$

Where α represents the intercept and is constant, β represents the coefficient of trend, and p is the order of lag of the autoregressive (AR) process. The unit root test is then carried out under the null hypothesis $\gamma=0$ against the alternative hypothesis of $\gamma < 0$. If $\gamma < 0$, then the series is stationary because there is no trend in the time series.

3.6. *ARIMA model*

ARIMA means Autoregressive Integrated Moving Average. It is used in the time series analysis to forecast upcoming series points. ARIMA consists of three components: Autoregressive (AR), Integrated (I), and Moving Average (MA). ARIMA models are denoted by ARIMA (p, d, q) where p is the number of auto-regressive orders, d is the order of differencing applied to the time series, and q denotes the number of moving average orders of the data series. The parameters p, d, and q are non-negative integers.

ARIMA model requires the data set to be stationary. It can also be applied to non-stationary data sets by eliminating the non-stationarity of the mean function by introducing an initial differencing step one or more times. ARIMA models for different p, d, and q values are developed, and the best model is selected using the Bayesian information criterion (BIC).

ARIMA (p, d, q) is given as follows:

$$\bar{z}_t = \emptyset_1 \bar{z}_{t-1} + \emptyset_2 \bar{z}_{t-2} + \cdots + \emptyset_p \bar{z}_{t-p} + a_t - \theta_1 \bar{z}_{t-1} - \theta_2 \bar{z}_{t-2} - \cdots \theta_q \bar{z}_{t-q} \quad (1)$$

Where $\bar{z}_t = z_t - \mu$ and a_t is the shock.

Equation (1) can be applied after finding the backward shift operator (B) as follows:

$\emptyset(B)(1-B)^d z_t = \theta(B) a_t$

4. Results and Discussion

4.1. *Descriptives analysis*

The mean, standard deviation, and coefficient of variation are calculated for monthly, seasonal, and yearly rainfall and average temperature (Table 1). Mean rainfall for the period 1975-2023 is 863.57 mm with a standard deviation of 406.95 mm. CV % indicates that there is a 47.12 % variation in yearly rainfall. Monson has the least variation (51.95 %) among seasonal rainfall, whereas winter rainfall has a large variation (123.26 %). In monthly rainfall, the least variation is observed for August (65.67 %), and the highest variation is observed for November (225.83 %). The least rainfall was observed in the year 1984 (218.44 mm), and the highest rainfall was observed in the year 2021 (1658.36 mm). The maximum rainfall is observed in the monsoon season (79.68 %) and August (23.98 %) months, whereas the minimum rainfall is observed in the winter season (3.46 %) and December (0.98 %) months. For the period 1975-2023, annual excess rainfall is observed for 8 years, while deficit rainfall is observed for 12 years [Table 2]. Excess and deficit rainfall in the monsoon season are observed for 8 years and 12 years, respectively. An interrelation between excess and deficit rainfall is observed for monsoon and annual rainfall. If the monsoon receives deficit rainfall in a year, then annual rainfall is also deficit in that year (except year 1982). If the monsoon receives excess rainfall in a year, then annual rainfall is also excess in that year (except in the year 2022). Post-monsoon and winter rainfall are never deficit.

The mean average temperature for the period 1975-2023 is 24 ºC with a standard deviation of 0.45 ºC. The lowest average temperature was observed in year 1978 (23.18 ºC), and the highest average temperature was observed in 2016 (25.49 ºC). The yearly average temperature has a variation of 1.90 %. The least seasonal variation is observed for monsoons (2.24 %), whereas the highest variation is observed for winter (4.82 %). The least monthly variation for average temperature is observed for August (1.87 %), whereas the highest variation is observed for February (6.05 %).

La Nina causes excess Rainfall in India, whereas El Nino causes deficit or at times normal rainfall [17]. The rainfall pattern of Ranchi does not show any fluctuation because of El Nio or La Nia events. In the period 1975-2023, 18 La Nina and 17 El Nino episodes happened (Table 3). During this 17 El Nino period, the annual rainfall is normal in eleven episodes, excess in two episodes, and deficit only in four episodes (1976, 1979, 1986, 1987). During 18 La Nina episodes, annual rainfall is normal in eleven episodes, deficit in three episodes and excess only in four episodes (2008, 2011, 2017, 2021).

Table 1. Statistical descriptives of rainfall and temperature for the period 1975-2023.

	Rainfall			Temperature		
	Mean	St. dev.	CV%	Mean	St. dev.	CV%
January	16.061	27.359	170.345	16.720	0.966	5.776
February	13.874	23.082	166.367	19.969	1.209	6.053
March	16.585	21.774	131.281	24.781	1.428	5.763
April	19.943	27.976	140.282	29.113	1.492	5.124
May	32.154	47.052	146.332	30.122	1.396	4.636
June	129.128	103.671	80.286	28.385	1.609	5.669
July	202.257	145.918	72.145	26.068	0.619	2.373
August	207.125	136.022	65.671	25.706	0.481	1.870
September	149.600	119.701	80.010	25.617	0.648	2.531
October	56.199	77.810	138.457	24.085	0.733	3.043
November	12.308	27.795	225.835	20.366	0.940	4.615
December	8.509	16.911	198.738	17.064	0.844	4.945
Summer	68.682	54.001	78.624	28.005	1.012	3.613
Monsoon	688.113	357.514	51.956	26.429	0.593	2.246
Post Monsoon	76.842	92.360	120.195	20.505	0.623	3.041
Winter	29.936	36.899	123.263	18.344	0.886	4.829
Annual	863.572	406.954	47.124	23.992	0.457	1.904

Table 2. Excess and deficit rainfall for the period 1975-2023.

Annual		Summer		Monsoon		Post Monsoon		Winter	
Deficit	Excess	Deficit	Excess	Deficit	Excess	Deficit	Excess	Deficit	Excess
1975	1993	1984	1977	1975	1993	Nil	1991	Nil	1978
1976	1994	1985	1994	1976	1994		1994		1979
1979	2006	1987	2020	1979	2006		1995		1982
1980	2008	1996	2021	1980	2008		1998		1983
1983	2011	2005		1982	2011		2013		1994
1984	2013	2017		1983	2017		2021		1998
1985	2017			1984	2021		2023		2005
1986	2021			1985	2022				2012
1987				1986					
1989				1987					
1990				1989					
1992				1990					

Table 3. El Nino and La Nina episodes in the period 1975-2023.

El-Nino				La-Nina		
Very Strong	Strong	Moderate	Weak	Weak	Moderate	Strong
1982	1987	1986	1976	1983	1995	1975
1997	1991	1994	1977	1984	2011	1988

2015	2023	2002	1979	2000	2020	1998
		2009	2004	2005	2021	1999
			2006	2008		2007
			2014	2016		2010
			2018	2017		
				2022		

4.2. *Trend analysis*

Seasonal rainfall for summer, monsoon, post-monsoon, winter, and annual rainfall is analyzed for trend (Table 4). Monsoon and annual rainfall have a significant upward trend, and no other seasons have any significant trend. The shift point for the increasing trend of monsoon and annual rainfall is observed to be 1993 and 1996, respectively (Fig. 2). The rainfall pattern started to move significantly in an upward direction for monsoon rainfall from year 1993 and for annual rainfall from year 1996. The monthly rainfall of June, July, August, September, and October have significant positive trends, and no other months have any significant trends. The seasonal and annual average temperatures are analyzed for possible trends, and it is observed that no significant trend is present for seasonal or annual average temperatures. However, the monthly average temperature for August has a significant positive trend.

Table 4. Trend analysis of rainfall and temperature for the period 1975-2023.

	Rainfall			Average Temperature		
	Z	β	Trend	Z	β	Trend
January	-0.44	0		-0.90	-0.008	
February	0.32	0		0.40	0.007	
March	0.54	0.008		0.25	0.003	
April	-0.44	-0.025		-0.38	-0.004	
May	1.73	0.327		-1.31	-0.018	
June	2.54	1.931	PT	0.61	0.013	
July	1.96	4.760	PT	1.51	0.012	
August	2.92	4.949	PT	2.04	0.017	PT
September	3.56	3.298	PT	1.78	0.013	
October	2.00	0.549	PT	-0.98	-0.011	
November	-0.99	0		-0.57	-0.007	
December	0.58	0		-1.17	-0.10	
Summer	0.49	0.206		-0.28	-0.003	
Monsoon	2.16	14.445	PT	1.89	0.013	
Post Monsoon	1.71	0.730		-1.00	-0.007	
Winter	0.53	0.116		-0.76	-0.010	
Annual	2.27	17.825	PT	-1.02	-0.005	

PT denotes a Positive trend; NT denotes a Negative trend.

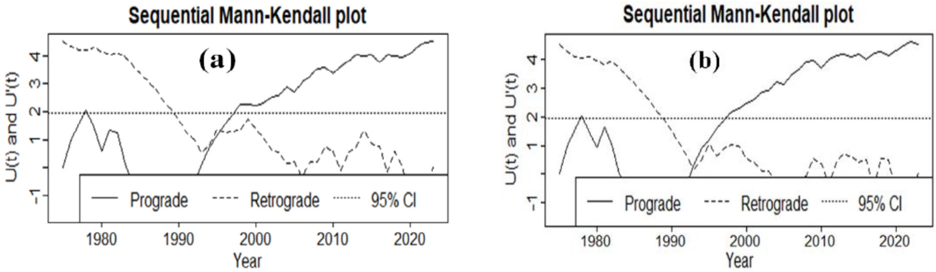

Fig. 2. Shift point of pattern for (a) annual and (b) monsoon rainfall.

4.3. *Correlation analysis*

Correlation coefficients are calculated to find out the interrelation of seasonal and annual rainfall with seasonal and annual average temperature (Table 5). Seasonally, summer rainfall is negatively correlated with summer average temperature at a 95 % confidence level. Annual rainfall is also negatively correlated with annual average temperature at a 95 % confidence level. Monthly Rainfall and monthly average temperature have a negative correlation for March, May, and June at a 99 % confidence level and for July, September, and December at a 95 % confidence level.

Table 5. Correlation analysis of rainfall and temperature.

Month	Correlation coefficient	p value
January	0.050	0.734
February	-0.090	0.539
March	-0.536**	0.000
April	-0.259	0.072
May	-0.410**	0.003
June	-0.459**	0.001
July	-0.333*	0.019
August	-0.035	0.812
September	-0.339*	0.017
October	-0.279	0.052
November	0.159	0.275
December	-0.353*	0.014
Summer	-0.318*	0.026
Monsoon	-0.215	0.137
Post Monsoon	-0.229	0.114
Winter	-0.155	0.289
Annual	-0.283*	0.049

* and ** denotes 95 % (p value <0.05) and 99 % (p value <0.01) confidence level respectively.

4.4. *Forecasting*

Seasonal and annual rainfall and average temperature are forecasted for the period 2024-2050 using the most suitable ARIMA model. The historical rainfall and average temperature data from 1975 to 2023 are used to train the model. The augmented Dickey-Fuller test suggests that the differencing of 1 makes the data stationary (Table 6). Hence, the differencing parameter of ARIMA is set to 1 while autoregressive and moving average parameters are selected in such a way that the normalized BIC value of the model is less. ARIMA (0,1,1) is found to be the most accurate model for the prediction of rainfall as well as average temperature (Table 7). The forecasted rainfall pattern is plotted in Fig. 3, and the forecasted values are mentioned in Table 8.

Trend analysis of forecasted rainfall and temperature emphasizes that a positive trend is present in summer, monsoon, post-monsoon, and annual, whereas a negative trend is present in Winter (Table 9). Also, the trend analysis of future average temperature has a positive trend for monsoon and the rest of other seasons, and the annual trend is negative.

Table 6. Unit root test for rainfall and temperature.

	Rainfall				Temperature			
	No differencing		Differencing=1		No differencing		Differencing=1	
	t value	p value	t value	p value	t value	p value	t value	p value
Annual	-0.225	0.559	-6.357	0.000	0.097	0.708	-8.019	0.000
Summer	-1.437	0.138	-6.119	0.000	-0.093	0.646	-6.639	0.000
Monsoon	-0.214	0.603	-8.267	0.000	0.421	0.800	-8.153	0.000
Post-Monsoon	-1.545	0.113	-8.086	0.000	-0.342	0.556	-8.187	0.000
Winter	-2.690	0.008	-7.232	0.000	0.012	0.681	-8.357	0.000

Table 7. Normalized BIC value of various ARIMA models.

Models	Normalized BIC (Rainfall)	Normalized BIC (Temperature)
ARIMA(0,1,1)	9.648	-0.485
ARIMA(1,1,1)	9.726	-0.401
ARIMA(0,1,3)	9.830	-0.341
ARIMA(0,1,2)	9.732	-0.408
ARIMA(0,2,1)	10.231	0.174

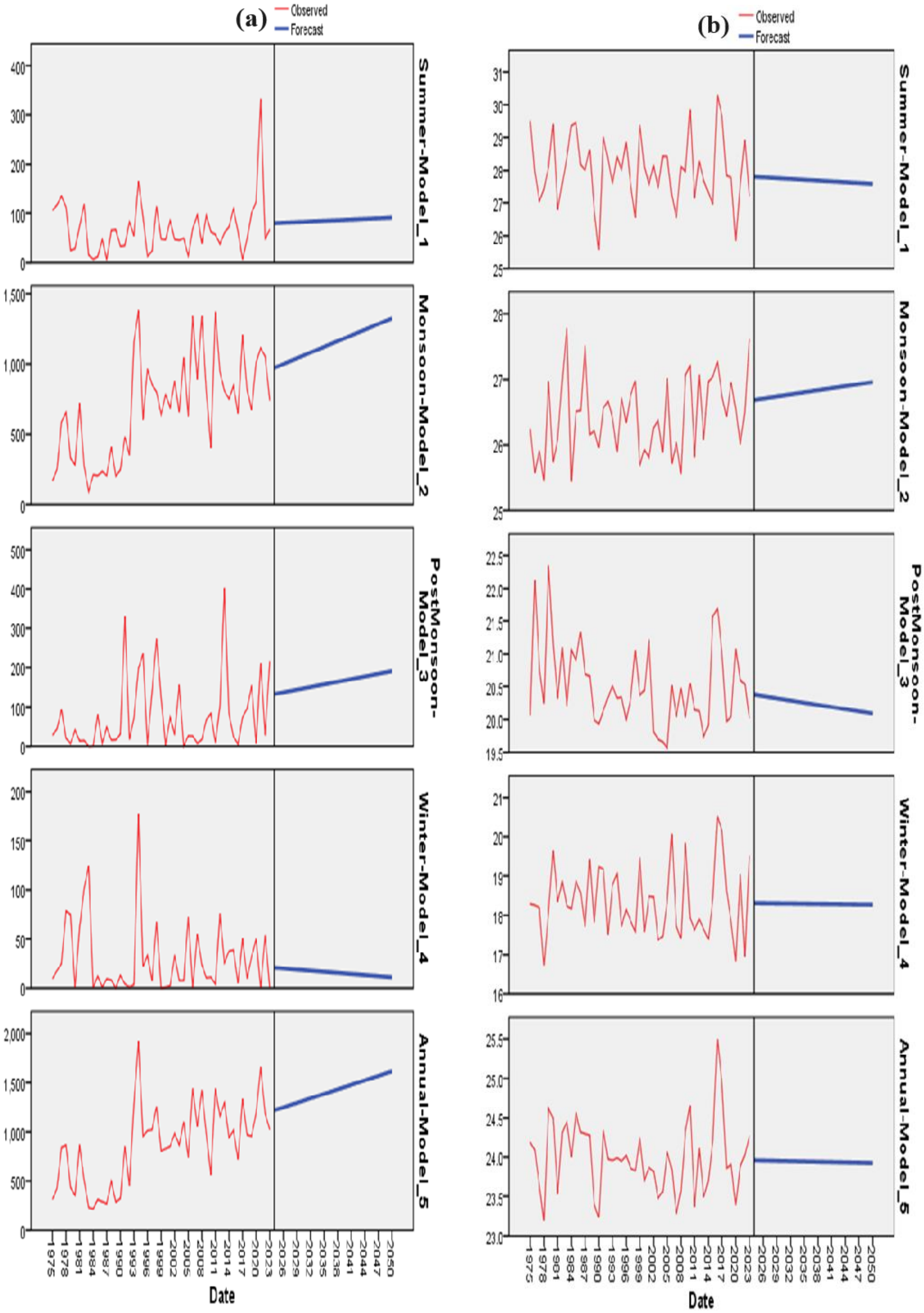

Fig. 3. Forecasting plots of (a) rainfall and (b) temperature.

Table 8. Forecasted values of rainfall and temperature.

Years	Annual		Summer		Monsoon		Post-Monsoon		Winter	
	Rain (mm)	Avg. Temp. (ºC)	Rain (mm)	Avg. Temp. (ºC)	Rain (mm)	Avg. Temp. (ºC)	Rain (mm)	Avg. Temp. (ºC).	Rain (mm)	Avg. Temp. (ºC)
2024	1218.11	23.960	79.76	27.797	971.65	26.688	132.85	20.378	20.81	18.308
2025	1233.37	23.959	80.20	27.788	985.23	26.698	135.09	20.367	20.44	18.307
2026	1248.63	23.958	80.64	27.780	998.81	26.708	137.33	20.356	20.08	18.305
2027	1263.88	23.956	81.09	27.772	1012.39	26.719	139.57	20.345	19.71	18.304
2028	1279.14	23.955	81.53	27.763	1025.97	26.729	141.81	20.334	19.35	18.302
2029	1294.40	23.954	81.97	27.755	1039.55	26.739	144.05	20.323	18.98	18.301
2030	1309.65	23.952	82.42	27.747	1053.14	26.750	146.29	20.311	18.62	18.300
2031	1324.91	23.951	82.86	27.738	1066.72	26.760	148.53	20.300	18.25	18.298
2032	1340.16	23.950	83.30	27.730	1080.30	26.770	150.77	20.289	17.89	18.297
2033	1355.42	23.949	83.74	27.722	1093.88	26.781	153.01	20.278	17.52	18.295
2034	1370.68	23.947	84.19	27.713	1107.46	26.791	155.25	20.267	17.16	18.294
2035	1385.93	23.946	84.63	27.705	1121.04	26.801	157.50	20.256	16.79	18.292
2036	1401.19	23.945	85.07	27.697	1134.62	26.812	159.74	20.245	16.43	18.291
2037	1416.45	23.944	85.52	27.688	1148.20	26.822	161.98	20.233	16.06	18.289
2038	1431.70	23.942	85.96	27.680	1161.78	26.832	164.22	20.222	15.70	18.288
2039	1446.96	23.941	86.40	27.672	1175.36	26.843	166.46	20.211	15.33	18.287
2040	1462.21	23.940	86.85	27.663	1188.94	26.853	168.70	20.200	14.97	18.285
2041	1477.47	23.938	87.29	27.655	1202.52	26.863	170.94	20.189	14.60	18.284
2042	1492.73	23.937	87.73	27.647	1216.11	26.874	173.18	20.178	14.24	18.282
2043	1507.98	23.936	88.17	27.638	1229.69	26.884	175.42	20.167	13.87	18.281
2044	1523.24	23.935	88.62	27.630	1243.27	26.894	177.66	20.156	13.51	18.279
2045	1538.49	23.933	89.06	27.622	1256.85	26.905	179.90	20.144	13.14	18.278
2046	1553.75	23.932	89.50	27.613	1270.43	26.915	182.14	20.133	12.78	18.276
2047	1569.01	23.931	89.95	27.605	1284.01	26.926	184.38	20.122	12.41	18.275
2048	1584.26	23.929	90.39	27.597	1297.59	26.936	186.62	20.111	12.05	18.274
2049	1599.52	23.928	90.83	27.588	1311.17	26.946	188.86	20.100	11.68	18.272
2050	1614.78	23.927	91.27	27.580	1324.75	26.957	191.10	20.089	11.32	18.271

Table 9. Trend analysis of forecasted rainfall for the period 2024-2050.

	Rainfall			Temperature		
	Z	B	Trend	Z	B	Trend
Summer	6.30	0.443	PT	6.44	-0.008	NT
Monsoon	6.17	13.581	PT	4.28	0.010	PT
Post Monsoon	3.13	2.240	PT	-5.64	-0.011	NT
Winter	-6.35	-0.365	NT	-4.36	-0.001	NT
Annual	6.74	15.256	PT	-4.57	-0.002	NT

5. Conclusion

The historical rainfall and average temperature for the period 1975-2023 have been analyzed, and it is observed that the annual mean rainfall is 863.57 mm and the annual mean temperature is 24 ºC. Monsoon (79.68 %) and August (23.98 %) contribute the highest rainfall to the annual rainfall, whereas winter (3.46 %) and December (0.98 %) contribute the least rainfall. It is also observed that the El Nio and La Nina have no impact on Ranchi's rainfall pattern. Trend analysis of rainfall suggests a significant positive trend in the Annual Monsoon, June, July, August, September, and October. However, the trend analysis of temperature showed a significant positive trend only for August. Correlation analysis of rainfall and average temperature suggests that a negative correlation exists for annual, summer, March, May, and June at a 99 % confidence level while for July, September, and December, the correlation is negative at a 95 % confidence level. The forecasting of rainfall and average temperature is done using the ARIMA model, and ARIMA (0,1,1) was found to be the most accurate model for the prediction. The best-fit model is selected on the basis of a lower normalized BIC value. The trend analysis of future rainfall suggests that a positive trend is present in summer, monsoon, post-monsoon, and annual, whereas a negative trend is present in winter. Also, the trend analysis of future average temperature shows a positive trend only for monsoon while the rest of other seasons and annual trend is negative.

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