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Annual and Seasonal Trend Analysis of Rainfall and Temperature Pattern in Arpa Catchment, Chhattisgarh

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ABSTRACT: Changes in precipitation occur due to global or local climate changes. Climate change has a major impact on precipitation patterns. Changes in rainfall as a result of global warming will have an impact on the hydrological cycle, stream flow patterns, and demand (especially in agriculture). This study examines the trends in seasonal and annual rainfall, minimum temperature and maximum temperature (T_{min} and T_{max}) using the Mann–Kendall (MK) test and Sen's slope (SS) method. Four rainfall and temperature stations located inside and near the study area were taken. Trend analysis was conceded out on seasonal and annual basis considering four seasons i.e. winter, summer, south west monsoon (SWM) and north east monsoon (NEM). Trend test for precipitation showed that increasing trend for all four stations (Ghatora, Andhiyarkore, Jondhra and Pendra) and for all season except Ghatora station in south west monsoon (SWM) showed decreasing trend. The annual trend of precipitation also shows increasing trend throughout the year. Minimum temperature shows increasing trends of Ghatora station for all season. Andhiyarkore and Jondhra station minimum temperature shows decreasing trends for winter season and all other season shows increasing trend, Pendra station shows decreasing trends for all season. The annual trend of minimum temperature throughout the 35 years' time period in all four stations had shown increasing trend. Maximum temperature shows decreasing trends for all season for all four station. The annual trend of maximum temperature throughout the 35 years' time period in all four stations shown decreasing trend.

Keywords: Rainfall, Maximum temperature, Minimum temperature, Mann-Kendall test, Sen's Slope Estimates and Trend Analysis.

INTRODUCTION

Climate is an important part of the earth's system. Weather and climate are comprised of various variables such as temperature, rainfall, atmospheric pressure, and humidity. The average weather is commonly used to define climate. Water resource management, hydrological modelling, flood forecasting, climate change studies, water balance computations, soil moisture modelling for crop production, irrigation scheduling, and other applications all require quantitative estimation of the spatial distribution of rainfall and temperature. The uncertainty of rainfall distribution and temperature change, both geographically and temporally, would be one of the most severe implications of global warming due to increased greenhouse gas emissions (Yadav *et al.*, 2014).

Changes in precipitation in a residential area can lead to important problems affecting human life. Change has significant effects on clean water resources and agricultural activities. Efficient use and control of water is provided by the correct evaluation and analysis of the meteorological data. In order to meet the needs, the management of water resources that change depending on time and quantity parameters is very important. Thus, the meteorological data should be examined on the presence of any trend (Ercan & Yüce 2017). An increase in temperature may result in heat-wave incidents, cause diseases and deaths in susceptible populations. Moreover, an increase in temperature may lead to more evaporation and cloud formation, which, in turn, increases rainfall (Alemu and Dioha 2020).

To test the trends in rainfall, Tmax, and Tmin, the Mann–Kendall (MK) test (Kendall, 1975; Mann, 1945) was used. It's a non-parametric test that doesn't require the data to be normally distributed to perform (Tabari *et al*., 2011). The MK test is based on the null hypothesis (H0), which states that there is no trend—the data are independent and randomly ordered—and is checked against the alternative hypothesis (Ha), which states that there is a trend. Sen's slope (SS) estimator (Sen, 1968) was used to predict the true slope (change per unit time) (Jain and Kumar 2012).

In based on the aforementioned issues, the current study was conducted in an attempt to determine the trend of the two most essential climatic variables, rainfall and temperature. Water management in the watershed will benefit from a trend study of seasonal and annual rainfall and temperature in the specified river basin. Using the XLSTAT. The XLSTAT statistical analysis add-in enhances Excel's analytical capabilities with a wide range of operations, making it the ideal tool for your regular data analysis and statistics needs. Because it is efficient, dependable, and simple to set up. XLSTAT has become one of the most widely used statistical software are available. It uses Excel to input data and display results, while the computations are handled by independent software components. XLSTAT is a user-friendly and extremely efficient statistical and multivariate data analysis programme mainly to its use of Excel as an interface. The computations are from the same high quality as those produced by traditional scientific statistical analysis software (Panda and Sahu, 2019).

MATERIALS AND METHODS

A. The Study Area

The Arpa River is a major tributary of the Mahanadi River, which is the state of Chhattisgarh perennial supply of irrigation. Arpa watershed is chosen for the present study. Ghatora gauging station at Arpa catchment and long term data related to climate, hydrology and land use are available, therefore choosen for the study. Khondari Khongsara, near Pendra (tehsil) in Bilaspur district, is the origin of the Arpa river. Arpa is around 147 km long. The river Kharang is a major tributary of Arpa river. The water flows from the north west to the south. The study area lies between 81°47′12″E to 8 82°14′48″E and 21°49′29″N to 22°45′27″N with a latitude ranges from 171-1076 m above mean sea level (MSL). The total catchment area for the Arpa river is 3192.28 sqkm. The climate of Arpa catchment is sub-tropical nature and average annual rainfall 1350 mm , where the maximum temperature in summer is 44.36°C and the minimum temperature in winter goes to the lowest of 16.6°C. Location map of study area shown in Fig. 1.

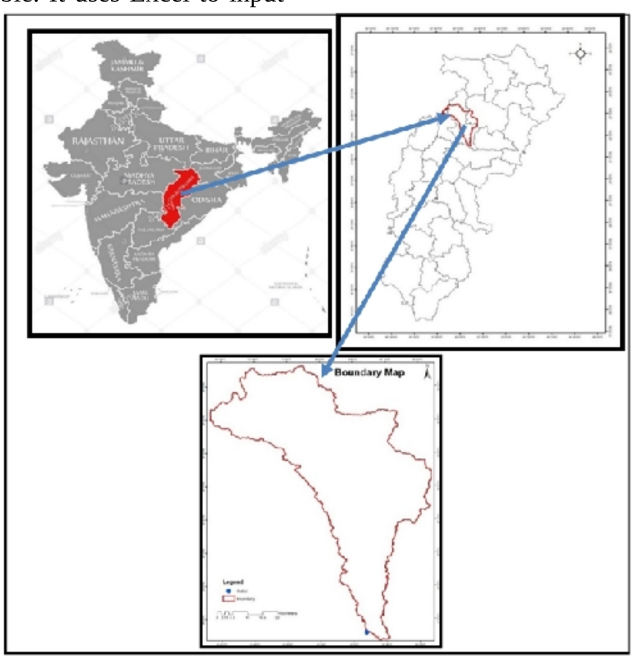

Fig. 1. Location map of Arpa Catchment.

B. Trend Analysis

A trend is a statistically significant change over time that may be identified using parametric and non-parametric methods, and trend analysis of a time series includes the magnitude of the trend as well as its statistical significance. The Man-Kendall test was used to determine the trend's statistical significance, while the non-parametric Sen's estimator approach was used to determine the trend's magnitude. For the trend test, observed precipitation, maximum and minimum temperature data were collected over a 35-year period (1985-2020) from Central Water Commission, Bhubaneshwar.

C. Mann–Kendall Test

In hydro-climatic time series data, this is a statistical approach for comparing the null hypothesis of no trend with the alternative hypothesis of a monotonic expanding or declining trend. The Mann-Kendall non-parametric test is ideal for data series with a monotonic trend (*i.e.*, a trend that is always increasing and never decreasing numerically) and no seasonal or other cycle. The M–K statistic is calculated as follows:

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

$$Sgn(xj - xi) = \begin{cases} +1, \text{if } xj - xi > 0 \\ 0, \text{if } xj - xi = 0 \\ -1, \text{if } xj - xi < 0 \end{cases} \quad (2)$$

$$\text{Var}(s) = \frac{1}{18}[n(n\text{-}1)(2n+5) - \sum_{p=1}^{q} t_p(t_p-1)(2t_p+5)] \quad (3)$$

$$Z = \begin{cases} \frac{s-1}{\sqrt{\text{Var}(s)}}, \text{if } S > 0 \\ 0 \ldots\ldots\ldots, \text{if } S = 0 \\ \frac{s+1}{\sqrt{\text{Var}(s)}}, \text{if } S < 0 \end{cases}$$

The statistical parameters are: Xi and Xj successive values of data in the years i and j, where n, the number of recorded data, t_p, the number of ties for the p^{th} values, and q, the number of tied values. Positive Z values indicate rising trend values, whereas negative Z values indicate decreasing trend values for the associated time series (Palaniswami and Muthiah, 2018). In the two-tailed test, Ho represents the null hypothesis and H1 represents the alternate hypothesis. Ho is rejected there is no trend in the series. If the series shows a trend, the Z value is calculated using the conventional normal distribution and the pre-determined significance threshold (Koudahe *et al.*, 2018).

D. Sen's slope Estimator

Theil-Sen method, a median-based non-parametric slope estimator, is used to determine the magnitude of the trend. The computation of slope is given by Equation 4.

$$\beta = \textbf{median}\frac{Xj - Xk}{j-k} \ldots \forall \ldots k < j \quad (4)$$

….. .where x_j and x_k are the successive data values of series in the year's j and k, and β is the magnitude of the trend slope data values.

RESULTS AND DISCUSSION

A. Trend analysis of precipitation and temperature

In this study trend analysis of rainfall and temperature of station Ghatora, Andhiyarkore, Jondhra and Pendra was done using Mann-Kendall trend test for 35 years of time series data (1985- 2020) on seasonally and annually basis. Data pertaining to trend of precipitation and temperature in all four stations of Arpa catchment has been deliberated and result on seasonal and annual basis were accessible as under:

B. Precipitation

Mann-Kendall trend test for precipitation analyzed for period of 1985-2020. Trend test for precipitation shows that increasing trend for all four stations (Ghatora, Andhiyarkore, Jondhra and Pendra) and for all season except Ghatora station in south west monsoon (SWM) shows decreasing trend.

Table 1: Results of the Mann-Kendall test for precipitation data.

Station Name	Season	Kendall's Tau	Mann- Kendall Statistic (S)	Var (S)	p-value (two tailed test)	alpha	Z	Sen's Slope (Q)
Ghatora	Winter	0.061	38	5345	0.613	0.05	0.51	0.14
	Summer	0.16	101	5390	0.173	0.05	1.36	1.40
	SWM	-0.225	-142	5390	0.055	0.05	-1.92	-10.45
	NEM	0.19	120	5390	0.105	0.05	1.62	4.23
	Annual Statistics	0.187	118	5390	0.111	0.05	1.59	8.19
Andhiyarkore	Winter	0.017	11	5389	0.892	0.05	0.14	0.08
	Summer	0.149	94	5390	0.205	0.05	1.27	0.61
	SWM	0.225	142	5390	0.055	0.05	1.92	8.02
	NEM	0.019	12	5390	0.881	0.05	0.15	0.18
	Annual Statistics	0.241	152	5390	0.04	0.05	2.06	7.70
Jondhra	Winter	0.033	21	5389	0.785	0.05	0.27	0.11
	Summer	0.156	98	5390	0.186	0.05	1.32	0.69
	SWM	0.2	126	5390	0.089	0.05	1.70	6.38
	NEM	0.038	24	5390	0.754	0.05	0.31	0.21
	Annual Statistics	0.232	146	5390	0.048	0.05	1.98	6.40
Pendra	Winter	0.063	40	5390	0.595	0.05	0.53	0.26
	Summer	0.225	142	5390	0.055	0.05	1.92	1.08
	SWM	0.171	108	5390	0.145	0.05	1.46	3.39
	NEM	0.044	28	5390	0.713	0.05	0.37	0.23
	Annual Statistics	0.181	114	5390	0.124	0.05	1.54	5.18

The annual trend of precipitation during the 35 years' time period in all four stations had shown increasing trend. Findings of the Mann-Kendall test for precipitation data in Table 1.

C. Trend analysis of maximum and minimum temperature

Minimum temperature shows increasing trends of Ghatora station for all season. Andhiyarkore and Jondhra station shows decreasing trends for winter season and all other season shows increasing trend. Pendra station shows decreasing trends for all season. The annual trend of minimum temperature during the 35 years' time period in all four stations had shown increasing trend. Results of the Mann-Kendall test for minimum temperature data in Table 2.

Maximum temperature shows decreasing trends for all season for all four station. The annual trend of maximum temperature throughout the 35 years' time period in all four stations had also shown decreasing trend. Results of the Mann-Kendall test for maximum temperature data in Table 3.

Table 2: Results of the Mann-Kendall test for minimum temperature.

Station Name	Season	Kendall's Tau	Mann- Kendall Statistic (S)	Var (S)	p-value (two tailed test)	alpha	Z	Sen's Slope (Q)
Ghatora	Winter	0.067	42	5390	0.577	0.05	0.56	0.019
	Summer	0.283	178	5390	0.016	0.05	2.41	0.068
	SWM	0.187	118	5390	0.111	0.05	1.59	0.030
	NEM	0.21	132	5390	0.074	0.05	1.78	0.048
	Annual Statistics	0.283	178	5390	0.016	0.05	2.41	0.049
Andhiyarkore	Winter	-0.149	-94	5390	0.205	0.05	-1.27	-0.017
	Summer	0.102	64	5390	0.391	0.05	0.86	0.010
	SWM	0.073	46	5390	0.54	0.05	0.61	0.004
	NEM	0.114	72	5390	0.334	0.05	0.97	0.011
	Annual Statistics	0.105	66	5390	0.376	0.05	0.89	0.005
Jondhra	Winter	-0.149	-94	5390	0.205	0.05	-1.27	-0.016
	Summer	0.086	54	5390	0.47	0.05	0.72	0.012
	SWM	0.076	48	5390	0.522	0.05	0.64	0.004
	NEM	0.108	68	5390	0.361	0.05	0.91	0.011
	Annual Statistics	0.102	64	5390	0.391	0.05	0.86	0.005
Pendra	Winter	-0.168	-106	5390	0.153	0.05	-1.43	-0.037
	Summer	-0.152	-96	5390	0.196	0.05	-1.29	-0.029
	SWM	0.067	42	5390	0.577	0.05	-0.75	-0.007
	NEM	0.283	178	5390	0.016	0.05	-0.37	-0.009
	Annual Statistics	0.187	118	5390	0.111	0.05	0.56	-0.019

Table 3: Results of the Mann-Kendall test for maximum temperature

Station Name	Season	Kendall's Tau	Mann- Kendall Statistic (S)	Var (S)	p-value (two tailed test)	alpha	Z	Sen's Slope (Q)
Ghatora	Winter	-0.2	-126	5390	0.089	0.05	-1.70	-0.066
	Summer	-0.327	-206	5390	0.005	0.05	-2.79	-0.109
	SWM	-0.127	-80	5390	0.282	0.05	-1.08	-0.029
	NEM	-0.165	-104	5390	0.161	0.05	-1.40	-0.048
	Annual Statistics	-0.225	-142	5390	0.055	0.05	-1.92	-0.075
Andhiyarkore	Winter	-0.283	-178	5390	0.016	0.05	-2.41	-0.060
	Summer	-0.194	-122	5390	0.099	0.05	-1.65	-0.033
	SWM	-0.079	-50	5390	0.505	0.05	-0.67	-0.007
	NEM	-0.13	-82	5390	0.27	0.05	-1.10	-0.022
	Annual Statistics	-0.298	-188	5390	0.011	0.05	-2.55	-0.026
Jondhra	Winter	-0.273	-172	5390	0.02	0.05	-2.33	-0.061
	Summer	-0.21	-132	5390	0.074	0.05	-1.78	-0.037
	SWM	-0.057	-36	5390	0.634	0.05	-0.48	-0.008
	NEM	-0.13	-82	5390	0.27	0.05	-1.10	-0.016
	Annual Statistics	-0.251	-158	5390	0.032	0.05	-2.14	-0.027
Pendra	Winter	-0.152	-96	5390	0.196	0.05	-1.43	-0.037
	Summer	-0.152	-96	5390	0.196	0.05	-1.29	-0.029
	SWM	-0.089	-56	5390	0.454	0.05	-0.75	-0.007
	NEM	-0.044	-28	5390	0.713	0.05	-0.37	-0.009
	Annual Statistics	-0.187	-118	5390	0.111	0.05	-1.59	-0.019

CONCLUSIONS

In the Mann-Kendall non-parametric test, the Zc statistics shown the trend of the series for 35 years (1985-2020) for seasonally and annually basis. Magnitude of seasonal precipitation data estimated in seasonally time steps the peak value for the slope of precipitation (8.02 mm/year) trend line was found in Andhiyarkore station in south west monsoon (SWM) and lowest value for the slope of rainfall (-10.45 mm/year) trend line was found in SWM in Ghatora station. In annual time steps the peak value for the slope of precipitation (8.19 mm/year) trend line was found in Ghatora station. Magnitude of minimum temperature data estimated in annually time steps the highest value for the slope of temperature (0.049°C/year) trend line was found in Ghatora station and lowermost value for the slope of temperature (-0.019°C/year) trend line was found in Pendra station. Magnitude of maximum temperature data estimated in annually time steps the lowermost value for the slope of temperature (-0.075°C/year) trend line was found in Ghatora station.

FUTURE SCOPE

The current study will be helpful to policymakers such as governments and research organizations to understand the seasonal variation of precipitation and temperatures in different seasons. This study can also contribute to the future climate change mitigation policies by governments and organizations.

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Conflict of Interest. None.

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