ABSTRACT

Trends analysis is performed to find the pattern that prevails in Nagwan watershed area located in Hazaribagh district of Jharkhand (India) having very high average annual rainfall in the range of 1146 mm. The study aims to investigated the impacts of global warming by examine precipitation and temperature change over a period. Non-parametric MK test and Sen’s Slope estimator were used to assess the trend in long-term rainfall and temperature time series (1981-2019). The analysis has been carried out on monthly, seasonal and annual scale to identify meso-scale climate change effect on hydrological regime. The precipitation in the summer showed an increasing trend (Z value +1.67) and there was increasing trend in the seasonal rainfall which influences the total water availability in the watershed. There was increase in minimum temperature during summer season which shows the impact of global warming and may results in increasing the duration of the
summer season. The annual average minimum temperature in the watershed showed an increasing trend (Z value +2.08) at 0.05 level of significance indicated hot nights in the summer. The annual average maximum temperature in the watershed showed a decreasing trend (Z value -1.26). Fluctuation and change in trend of rainfall and temperature possess potential risk hence it is important to understand and identify the pattern of rainfall and temperature for assessing impact of climate change and it is necessary to adopt appropriate steps for agriculture crop planning and improving farmer's capability to cope with challenging situations due to environmental and climate changes.

Keywords: Climate change; Non-parametric mann-kendell; sen's slope; temperature.

1. INTRODUCTION

Availability of water resources is a major concern for any future planning and development including flood control, flood protection, drought mitigation and sustainable watershed management. The hydrological cycle which play a significant role in sustaining river system through rain are affected which resulted in inadequate water supply to fulfil the different demand mainly for agriculture, hydropower water supply, industry, etc. Uneven distribution of rainfall and unavailability of water influences the agriculture sector, food security and energy sector. Global climate changes affect the long-term rainfall pattern causes inadequate availability of water and resulted into a serious of drought and flood. Different methods were adopted to assess the trend of long-term rainfall pattern. Mann-Kendall test [1,2] is one of the best methods amongst them, which is preferred by various researchers [3,4]. Trend analysis of rainfall time series includes determination of increasing and decreasing trend by using non-parametric Mann-Kendell test and magnitude of trend using Sen's slope method [5].

The parametric tests are based on the assumption of the population distribution while, nonparametric tests do not contemplate any such assumptions and commonly used in the climatic study. Some of the examples of application different tests include t-test [6,7] Mann-Whitney and Pettitt test [8,9,10], linear and piecewise linear regression test [11,12,13], cumulative sum analysis test [8,14], hierarchical Bayesian change point analysis test [15], Markov chain Monte Carlo method [16], reversible jump Markov chain Monte Carlo algorithm [17] and nonparametric regression test [18].

"Mann-Kendall test does not require datasets to follow normal distribution and show homogeneity in variance [19]. Sen's slope estimation method gives the magnitude of trend. It assumes that trend line is a linear function in the time series. Sen's slope method shows the rise and fall of the variable through slope value [5]. Another advantage of using Sen's slope is that it is not affected when outliers and single data errors are present in the dataset [20]. The Mann Kendall's test is a statistical test recommended by the World Meteorological Organization for public application [21] and widely used for the analysis of trend in climatologic and hydrologic time series [22,23,24,25,26,27,28]. There are two advantages of using this test; first, this test does not require data to be normally distributed; second, this test has low sensitivity to abrupt breaks due to inhomogeneous time series [29].

The impact of climatic variability was studied based on temperature, precipitation and stream flows in the Yellow river basin of China and found that trend in climatic parameters had a significant impact on stream-flow, since it was sensitive to both precipitation and temperature [30]. Investigation was carried out using annual rainfall and monthly rainy days of twenty rain gauge stations in Iran for assessing the impact of climate change using Mann Kendall's test and found no significant climate change impacts on precipitation regime [31]. The analysis of evaporation and rainfall data of 58 stations distributed uniformly in India for the period of 30 years from 1971 to 2000 where annual, summer (March to May), winter (December to February), monsoon (June to September) and post-monsoon (October, November) periods at 95% level of confidence were computed. It has been observed that the evaporation in the country has significantly decreased in all seasons while there is no significant trend in rainfall. Out of 58 stations, 45 stations in annual, 30 in winter, 42 in summer and 35 in monsoon and post-monsoon season indicated the significant decreasing trend for evaporation [32].

Analysis of annual stream-flow and sediment discharge in the Wuding River and observed a
significant decreasing trend [33]. Trend assessment was carried out for rainfall for 30 sub-divisions in India and found that Chhattisgarh sub-division exhibited a significant downward trend out of 15 sub-divisions showing a decreasing trend in annual rainfall series [34]. Looking in the well acceptability of Mann-Kendall test and Sen’s slope for identification of trend in climatological series, the present study has been taken to analyze temporal changes using non-parametric Mann–Kendall test and its magnitude of change were determined using Sen’s slope methods.

2. MATERIALS AND METHODS

2.1 Study Area

The Nagwan watershed is situated at the Upper Damodar Valley, Hazaribagh district, Jharkhand. It has an area of 92.32 km² and lies between 85°16’41” and 85°23’50” E longitudes and 23°59’33” and 24°5’37” N latitudes. The area experiences sub-humid sub-tropical monsoon type of climate, characterized by hot summers (40°C) and mild winters (4°C). The watershed receives an average annual rainfall of 1272.5 mm, out of which more than 80% is received during monsoon season (June–October). The daily mean relative humidity varies from a minimum of 40% in the month of April to a maximum of 85% in the month of July. The soil which prevails in that region is mainly silty loam, loamy sand, and sandy loam. Fig. 1 show the location of study area.

2.2 Data Used

In order to assess impact of climate change, the historical precipitation and temperature data for 1981-2019 (i.e. 39 years) were employed to accomplish the research and had been collected from the Damodar Valley Corporation, Jharkhand. MK Test and Sen’s Slope test had been adopted for trend assessment and are briefly discussed below.
2.3 Mann-Kendall (MK) Test

Mann presented a non-parametric test for randomness against time, which constitutes a particular application of Kendall’s test for correlation commonly known as the ‘Mann-Kendall’ or the ‘Kendall t test’. Mann- Kendall test is a statistical test widely used for the analysis of trend in climatology and in hydrologic time series [35,36,37]. There are two advantages of using this test. First, it is a nonparametric test and does not require the data to be normally distributed. Secondly, the test has low sensitivity to abrupt breaks due to inhomogeneous time series [38].

The Mann-Kendall test statistic $S$ is calculated using the formula [39],

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

Where $x_i$ and $x_j$ are the annual values in years $i$ and $j$, respectively, ($i > j$) and $n$ is the number of data points. The value of $\text{sign}(x_i - x_j)$ is computed as follows:

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

This statistic represents the number of positive differences minus the number of negative differences for all the differences considered [40,41,42].

For sample size $n > 10$, the mean and variance are given by:

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

Where $m$ is the number of tied groups and $t_i$ is the number of ties of extent $i$ [43,44].

If there are no ties between the observations, the variance is computed as:

$$ \sigma^2(S) = \frac{n(n-1)(2n+5)}{18} $$

The standard normal test statistic $Z$ is computed as [45]:

$$ Z = \frac{S - 1}{\sqrt{\text{Var}(S)}} $$

if $S > 0$

$$ Z = 0 $$

if $S = 0$

$$ Z = \frac{S + 1}{\sqrt{\text{Var}(S)}} $$

if $S < 0$

The presence of a statistically significant trend is evaluated using the $Z$ value [46]. A positive value of $Z$ indicates an upward trend and its negative value a downward trend [47,48]. The $Z$ values were tested at 0.05 level of significance.

2.4 Sen’s Slope Estimator

The Sen’s nonparametric method is used to estimate the true slope of an existing trend. The slope $N$ of all data pairs is computed as [49]

$$ N = \frac{x_j - x_i}{j - i} $$

Where $x_i$ and $x_j$ are considered as data values at time $j$ and $i (j > i)$ correspondingly.

The median of these $n$ values of $Q$ is represented as Sen’s estimator of slope

If $N$ is odd

$$ Q = T_{N+1} \frac{N}{2} $$

If $N$ is even

$$ Q = \frac{1}{2} \left( T_{N+1} + T_{N+2} \frac{N}{2} \right) $$

Sen’s slope estimator is computed as $Q=T (N+1)/2$ if $N$ appears odd, and it is considered as $Q=T(N/2)+T(N+2)/2$ if $N$ appears even. At the end, $Q$ is computed by a two sided test at 100 (1-α) % confidence interval and then a true slope can be obtained by the non-parametric test. Positive value of $Q$ indicates an upward or increasing trend and a negative value of $Q$ gives a downward or decreasing trend in the time series.

3. RESULTS AND DISCUSSION

3.1 Statistical Analysis

The preliminary data analysis was carried out to find the statistical parameters (mean, standard deviation, and coefficient of variation) of average annual rainfall for the period 1981-2019. Annual precipitation in the watershed varies between 749.85 mm (1983) to 1459.9 mm (1994) with a standard deviation of 189.58 mm.
average precipitation is 1146.39 mm. Coefficient of variation (CV) was found to be 16.54%. All the statistical parameters computed for annual and seasonal basis are given in Table 1.

The rainfall variability in the region was high indicating climatic risk, which causes fluctuations in reservoir storage and crop yield from year to year. Agriculturally it is the more crucial parameter based on which suitable farming practices need be adopted, so as to render the impact of inter-annual variability which existed in the region.

3.1.1 Trend assessment of monthly, seasonal and annual rainfall

Trends in annual and seasonal rainfall series are commonly assessed using nonparametric Mann-Kendell test and its magnitude of change is detected using Sen’s Slope method. The results of MK test and Sen’s slope estimator are presented in Table 2. Fig. 2 showing the variation of the Mann-Kendall’s test statistics (Z value) and Sen’s slope (Q value) of the trend analysis.

The results shown in Table 2 indicated a falling trend in month of January, February, June, November and December at a significance level greater than 0.1 whereas significant rising trends showed in the months of May at 0.1 level of significance. The precipitation in the summer showed an increasing trend (Z value +1.67). There is an increasing trend in the seasonal rainfall which influences the total water availability in the watershed however; inadequate rainfall during winter may help to reduce post-harvest crop losses. A decreasing winter precipitation (Z value -1.33) will result in less water availability to winter crops.

Fig. 3 depicts the precipitation variability during the period 1981-2019 for different months, seasons and annual rainfall (mm).

3.2 Maximum Temperature (°C)

The statistical analysis was carried out to find out mean, standard deviation and coefficient of variance for annual maximum temperature for the period 1981-2019. Maximum annual temperature in the watershed varies between 29.9°C (2008) to 32.3°C (2010) where mean annual maximum temperature is 31.01°C with standard deviation 0.59°C. All the statistical parameters for annual and seasonal basis are shown in Table 3.

| Time series | MK Test statistics (Z) | Sen’s Slope(Q) | Significance |
|-------------|------------------------|----------------|--------------|
| January     | -0.76                  | -0.06          | -            |
| February    | -1.33                  | -0.21          | -            |
| March       | 0.60                   | 0.09           | -            |
| April       | 0.36                   | 0.06           | -            |
| May         | 1.65                   | 0.64           | +            |
| June        | -0.70                  | -0.46          | -            |
| July        | 0.46                   | 0.80           | -            |
| August      | 0.85                   | 1.01           | -            |
| September   | 0.97                   | 0.94           | -            |
| October     | 1.14                   | 0.52           | -            |
| November    | -1.48                  | -0.07          | -            |
| December    | -0.33                  | 0.00           | -            |
| Annual      | 1.11                   | 3.80           | -            |
| Seasonal    | 0.87                   | 2.38           | -            |
| Winter      | -1.33                  | -0.50          | -            |
| Summer      | 1.67                   | 0.68           | +            |

Note: + if trend at α = 0.1 level of significance, - trend at α > 0.1 level of significance
Fig. 2. Plot showing MK statistics (Z value) and Sen’s slope (Q value) for rainfall trend analysis.
Fig. 3. Variability in rainfall pattern in different months, seasons and annual rainfall

Trend analysis of Temperature

Table 3. Statistical parameter for annual and seasonal maximum temperature (°C)

| S. No.            | Mean (°C) | Maximum (°C in year) | Minimum (°C in year) | SD | CV (%) |
|-------------------|-----------|----------------------|----------------------|----|--------|
| Annual            | 31.01     | 32.3(2010)           | 29.90(2008)          | 0.59 | 1.90   |
| Seasonal rainfall | 32.19     | 33.9(1983)           | 30.47(2008)          | 0.88 | 2.75   |
| Winter Season     | 48.59     | 51.97(1990)          | 44.87(2012)          | 1.89 | 3.88   |
| Summer Season     | 37.85     | 39.83(2010)          | 35.97(1982)          | 0.94 | 2.48   |

3.2.1 Trend assessment of monthly, seasonal and annual maximum temperature (°C)

Trends in annual and seasonal maximum temperature series are computed using nonparametric Mann-Kendell test and its magnitude of change is detected using Sen’s Slope method. The results of MK test and Sen’s slope estimator are presented in Table 4.

The results shown in Table 4 indicated a falling trend in month of December at 0.05 level of significance and in the month of January at 0.1 level of significance, and in rest of the month there is decreasing trend with significant at 0.1 level of significance except in February, June, July, and September which has increasing trend at level of significance greater than 0.1. The annual average maximum temperature in the watershed showed a decreasing trend (Z value -1.26) and will affect the hydrological cycle which maintains the water level in that region. A significant decreasing trend (Z value -2.15) at 0.05 level of significance, during winter consequently decreases the crop productivity and may alter the soil moisture condition required for healthy crop growth. A decreasing seasonal maximum temperature will result in less evaporation loss causing to rise in the ground water table. Fig. 4 depicts the maximum temperature variability during the period 1981-2019.
Table 4. Represent the value for Mk test statistics and Sen’s slope for maximum temperature (°C)

| Time series | MK Test statistics (Z) | Sen Slope(Q) | Significance |
|-------------|------------------------|--------------|--------------|
| January     | -1.81                  | -0.032       | +            |
| February    | 0.44                   | 0.009        | -            |
| March       | -0.70                  | -0.018       | -            |
| April       | -0.75                  | -0.020       | -            |
| May         | -0.51                  | -0.006       | -            |
| June        | 0.22                   | 0.008        | -            |
| July        | 0.12                   | 0.002        | -            |
| August      | -0.82                  | -0.007       | -            |
| September   | 0.27                   | 0.002        | -            |
| October     | -0.36                  | -0.007       | -            |
| November    | -0.46                  | -0.007       | -            |
| December    | -2.01                  | -0.039       | *            |
| Annual      | -1.26                  | -0.013       | -            |
| Seasonal    | -0.51                  | -0.006       | -            |
| Winter      | -2.15                  | -0.065       | *            |
| Summer      | -0.73                  | -0.012       | -            |

Note: *if trend at α = 0.05 level of significance, + if trend at α = 0.1 level of significance, - trend at α > 0.1 level of significance.
Fig. 4. Maximum temperature variability during the period 1981-2019 for different months, season and annual rainfall

Table 5. Statistical parameter for annual and seasonal minimum temperature

| S.No.        | Mean | Maximum(Year) | Minimum(Year) | SD  | CV(%) |
|--------------|------|---------------|---------------|-----|-------|
| Annual       | 19.13| 20.13(2010)   | 18.47(1981)   | 0.34| 1.78  |
| Seasonal rainfall | 24.61| 25.35(2019)   | 23.71(1984)   | 0.39| 1.58  |
| Winter Season| 21.63| 24.04(2009)   | 18.66(2013)   | 1.22| 5.64  |
| Summer Season| 21.82| 23.67(2016)   | 20.43(1998)   | 0.68| 3.12  |

3.3 Minimum Temperature

For annual minimum temperature the statistical analysis was carried out to find out mean, standard deviation and coefficient of variance for the period of 1981-2019. Minimum annual temperature in the watershed varies between 18.47°C (1981) to 20.13°C (2010) whereas mean annual minimum temperature is 19.13°C with standard deviation 0.34°C. All the statistical parameters for annual and seasonal basis are shown in Table 5.

3.3.1 Trend assessment of monthly, seasonal and annual minimum temperature

Trends in annual and seasonal maximum temperature are assessed using nonparametric Mann-Kendell test and its magnitude of change is detected using Sen’s Slope method. The results of MK test and Sen’s slope estimator are presented in Table 6.

The results shown in Table 6 indicated a falling trend in month of January at 0.05 level of significance and in December at 0.1 level of significance, and in rest of the month there is increasing trend with significant at 0.1 level of significance except April and May which are significant at 0.05 level of significance. Increase in minimum temperature during summer season shows the impact of global warming which resulted in increasing summer temperature and thus influence growth of plants. The annual average minimum temperature in the watershed showed an increasing trend (Z value +2.08) at
0.05 level of significance. There is a decreasing trend in winter season (Z value -1.45) at significance level greater than 0.1. Fig. 5 to depict the minimum temperature variability during the period 1981-2019.

Table 6. Represent the value for MK test statistics and Sen slope for maximum rainfall data

| Time series | MK Test statistics (Z) | Sen Slope(Q) | Significance |
|-------------|------------------------|--------------|--------------|
| January     | -2.01                  | -0.031       | *            |
| February    | 1.57                   | 0.038        | -            |
| March       | 1.33                   | 0.024        | -            |
| April       | 2.30                   | 0.028        | *            |
| May         | 2.27                   | 0.020        | *            |
| June        | 1.74                   | 0.028        | +            |
| July        | 0.90                   | 0.008        | -            |
| August      | 1.60                   | 0.005        | -            |
| September   | 1.52                   | 0.010        | -            |
| October     | 1.62                   | 0.020        | -            |
| November    | 0.92                   | 0.014        | -            |
| December    | -1.16                  | -0.013       | -            |
| Annual      | 2.08                   | 0.012        | *            |
| Seasonal    | 2.08                   | 0.013        | *            |
| Winter      | -1.45                  | -0.021       | -            |
| Summer      | 2.61                   | 0.022        | **           |

Note: **if trend at α = 0.005 level of significance, *if trend at α = 0.05 level of significance, + if trend at α = 0.1 level of significance, - trend at α > 0.1 level of significance
4. CONCLUSION

The global average surface temperature has increased by 0.6 ± 0.2°C over the last century (IPCC, 2001) and it is expected that, by 2100, the increase in temperature could be 1.4–5.8°C. The change in temperature is not uniform globally, but varied from regions to regions. In order to assess base line trend in climate in Nagwan watershed trend analysis on rainfall, maximum and minimum temperatures on annual and seasonal data of 39 years. Non-parametric Mann Kendall test was applied to identify the trend and Sen’s slope estimator to determine the magnitude of change. From rainfall trend assessment it may be concluded that in summer, an increasing trend prevails and an increasing trend in seasonal rainfall as well which influences the total water availability in the watershed. Maximum temperature data indicated a falling trend in month of December and January which affect the Rabi season crop. The annual average maximum temperature in the watershed showed a decreasing trend and thus affects the hydrological cycle. A decreasing trend during winter consequently decreases the crop productivity and may alter the soil moisture condition required for healthy crop growth. The minimum temperature showed falling trend in January and December and increasing trend in rest of the month. Increase in minimum temperature during summer season shows the impact of global warming resulted in increasing summer temperature and thus influence growth of plants. The watershed showed impact of climate change due to global warming which mainly influence Rabi season (December and January). Due to variability in rainfall and temperature there is decline in yield of crop and therefore different strategies need to be adopted to render the impact of climate change through planning and suitable water resources management.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.
REFERENCES

1. Mann HB. Nonparametric tests against trend. Econometrica. 1945;13:245–259.
2. Kendall MG. Rank Correlation Methods. London: Charles Griffin; 1975.
3. Douglas EM, Vogel RM, Knoll CN. Trends in flood and low flows in the United States: Impact of spatial correlation. J. Hydrol. 2000;240:90–105.
4. Yue S, Hashino M. Long term trends of annual and monthly precipitation in Japan. J Am Water Resour. 2003;39(3):587–596.
5. Jain SK, Kumar V. Trend analysis of rainfall and temperature data for India. Curr Sci. 2012; 102(1):37–49.
6. Marengo JA, Camargo CC. Surface air temperature trends in southern Brazil for 1960–2002. Int J Climatol. 2008;28:893–904.
7. Staudt M, Esteban-Parra, Castro-Diez Y. Homogenization of long-term monthly Spanish temperature data. Int J Climatol. 2007;27:1809–1823.
8. Fealy R, Sweeney J. Detection of a possible change point in atmospheric variability in the north Atlantic and its effect on Scandinavian glacier mass balance. Int J Climatol. 2005;25:1819–1833.
9. Mauget SA. Intra to multi-decadal climate variability over the continental United States. Int J Climatol. 2003;16:2215–2231. DOI: 10.1002/jcli.1823.
10. Yu PS, Yang TC, Kuo CC. Evaluating long-term trends in annual and seasonal precipitation in Taiwan. Water Resour Manag. 2006;20:1007–1023.
11. Portnyagin YI, Merzlyakov EG, Solovjova TV, Jacobi C, Kurschner D, Manson A, Meek C. Long-term trends and year-to-year variability of mid-latitude mesosphere/lower thermosphere winds. J Atmos Solut Terr Phys. 2006;68:1890–1901.
12. Su BD, Jiang T, Jin WB. Recent trends in observed temperature and precipitation extremes in the Yangtze river basin, China. Theor Appl Climatol. 2006;83:139–151.
13. Tomé AR, Miranda PMA. Piecewise linear fitting and trend changing points of climate parameters. Geophys Res Lett. 2004; 31:L02207.
14. Levin N. Climate-driven changes in tropical cyclone intensity shape dune activity on Earth’s largest sand island. Geomorphology. 2011;125:239–252. DOI: 10.1016/j.geomorph.2010.09.021
15. Tu JY, Chou C, Chu PS. The abrupt shift of typhoon activity in the vicinity of Taiwan and its association with western north Pacific–East Asian climate change. J Clim. 2009;22:3617–3628.
16. Elsner JB, Niu X, Jagger TH. Detecting shifts in hurricane rates using a Markov chain Monte Carlo approach. J Clim. 2004;17:2652–2666.
17. Zhao X, Chu PS. Bayesian changepoint analysis for extreme events (typhoons, heavy rainfall, and heat waves): an RJMCMC approach. J Clim. 2010;23:1034–1046. DOI: 10.1175/2009JCLI2597.1
18. Bates BC, Chandler RE, Charles SP, Campbell EP. Assessment of apparent non-stationarity in time series of annual inflow, daily precipitation and atmospheric circulation indices: A case study from southwest Australia. Water Resour Res. 2010;46:W00H02.
19. Duhan, Darshana, and Ashish Pandey. Statistical analysis of long term spatial and temporal trends of precipitation during 1901-2002 at Madhya Pradesh, India. Atmospheric Research. 2013;122: 136–49. DOI: https://doi.org/10.1016/j.atmosres.2012.10.010
20. Salmi Timo, Anu Maatta, Pia Anttila, Tuija Ruoho-Airola, Toni Amnell. Detecting trends of annual values of atmospheric pollutants by the mann-kendall test and sen’s slope estimates the excel template application MAKESENS. Finnish Meteorological Institute, Air Quality Research; 2002.
21. Mitchell JM, Dzezzerdzeeskii B, Flohn H, Hofmeyer WL, Lamb HH, Rao KN, Wallen CC. Climatic change. WMO Technical Note 79, WMO No. 195.TP-100, Geneva. 1996;79.
22. Burn DH, Elnur MA. Detection of hydrologic trends and variability. J Hydrol. 2002;255(1–4):107–122
23. Hirsch RM, Slack JR, Smith RA. Techniques of trend analysis for monthly water quality data. Water Resour Res. 1982;1:107–121.
24. Kahya E, Kalayci C. Trend analysis of streamflow in Turkey. J Hydrol. 2004;289:128–144.
25. Mavromatis T, Stathis D. Response of the water balance in Greece to temperature and precipitation trends. Theor Appl Climatol. 2011.

26. Yue S, Pilon P. A comparison of the power of the t test, Mann-Kendall and bootstrap tests for trend detection. Hydrol Sci J. 2004;49(1):21–37.

27. Yue S, Pilon P, Phinney B. Canadian stream-flow trend detection: impacts of serial and cross-correlation. Hydrol Sci J. 2003;48(1):51–63.

28. Yue S, Wang C. The Mann-Kendall Test Modified by Effective Sample Size to Detect Trend in Serially Correlated Hydrological Series. Water Resour Manag. 2004;18:201–218.

29. Tabari H, Marofi S. Changes of pan evaporation in the west of Iran. Water Resour Manag. 2011;25:97–111.

30. Fu GB, Charles SP, Viney NR, Chen S, Wu JQ. Impacts of climate variability on stream-flow in the Yellow River. Hydrol Process. 2007;21(25):3431–3439.

31. Modarres R, Da Silva V. Rainfall trends in arid and semi-arid regions of Iran. J Arid Environ. 2007;70:344–355.

32. Jaiswal AK, Prakash Rao GS, De US. Spatial and temporal characteristics of evaporation trends over India during 1971–2000. Mausam. 2008;59(2):149–158.

33. Gao P, Mu XM, Li R, Wang W. Trend and driving force analyses of streamflow and sediment discharge in Wuding River. J Sediment Res. 2009;5:22–28.

34. Kumar Vijay, Sharad K. Jain, Yatveer Singh. Analyse Des Tendances Pluviométriques de Long Terme En Inde. Hydrological Sciences Journal. 2010;55(4):484–96. DOI:https://doi.org/10.1080/02626667.2010.481373.

35. Jaiswal RK, Lohani AK, Tiwari HL. Statistical Analysis for Change Detection and Trend Assessment in Climatological Parameters. Environmental Processes. 2015;2(4):729–749. DOI:https://doi.org/10.1007/s40710-015-0105-3

36. Kocsis T, Kovács-Székely I, Anda A. Homogeneity tests and non-parametric analyses of tendencies in precipitation time series in Keszhely, Western Hungary. Theoretical and Applied Climatology. 2020;139(3–4):849–859.

37. DOI:https://doi.org/10.1007/s00704-019-03014-4

38. Thesis MP. Analysis of Trend of the Precipitation Data: A Case Study of Kangra District, Himachal Pradesh. International Journal of Research – GRANTHAALAYAH. 2015;3(9):87–95.

39. Tabari H, Marofi S, Aein I, Talaei KH, Mohammadi K. Trend analysis of reference evapotranspiration in the western half of Iran. Agric Forest Meteorol. 2011;151:128–136.

40. Jain SK, Kumar V, Saharia M. Analysis of rainfall and temperature trends in northeast India. International Journal of Climatology. 2013;33(4):968–978. DOI:https://doi.org/10.1002/joc.3483

41. Pandit DV. Seasonal Rainfall Trend Analysis. Journal of Engineering Research and Application. 2016;6(7):69–73. Available: www.ijera.com

42. Yue S, Hashino M. Temperature trends in Japan: 1900–1990. Theoret. Appl. Climatol. 2003;75:15–27.

43. Afouda A. Trends and Changes in Recent and Future Penman-Monteith Potential Evapotranspiration in 7–16; 2017. DOI:https://doi.org/10.3390/hydrology4030038

44. Yu X, Zhao G, Zhao W, Yan T, Yuan X. Analysis of precipitation and drought data in Hexi Corridor, northwestern China. Hydrology. 2017;4(2):1–12. DOI:https://doi.org/10.3390/hydrology4020029

45. Li S, Lund RB. Multiple change point detection via genetic algorithms. J Clim. 2012;25:674–686.

46. Dodamani AAPBM. Trend analysis of rainfall, rainy days and drought: A case study of Ghapatrabha River Basin, India. Modeling Earth Systems and Environment, (0123456789); 2020. DOI:https://doi.org/10.1007/s40808-020-00798-7

47. Thomas T, Gunthe SS, Sudheer KP, Ghosh NC. Analysis of monsoon rainfall variability over Narmada Basin in Central India: Implication of Climate Change.
48. Yue S, Pilon P, Phinney B. Canadian streamflow trend detection: Impacts of serial and cross-correlation. Hydrol. Sci. J. 2003;48(1):51–63.

49. Sen PK. Estimates of the regression coefficient based on Kendall’s tau. J. Am. Statist. Assoc. 1968;63:1379–1389.