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Climate Change Impact Studies on Rainfall Variability- A Case Study of Chhatarpur District, Madhya Pradesh, India

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Abstract
The impacts of anthropogenic activities on the earth atmosphere and its systems have been engaging attention of planners, governments and politicians worldwide. The countries across the world are engaged in working out the impacts and associated variability's to the projected climate change. In the twentieth century many recent studies show changes in rainfall patterns of India as well as changes in weather conditions. These are due to worldwide climate changes, decrease in rainfall duration and rainfall amount and increase in rainfall intensity. In the present paper describe Climate Change Impact Studies on Rainfall Variability: A case study of Chhatarpur District, Madhya Pradesh, India. The rainfall data collected for a period of 1901 to 2019from the District Land Record Department of Chhatarpur and Indian Meteorological Department, New Delhi (IMD). The results of 119 years old historical rainfall records of Chhatarpur district have been analysis using statistical and Mann-Kendall tests. Results are also discussed for the future climate change scenario in rainfall variability of thearea.

Keywords: *Climate change, rainfall variability, statistical, regression model and Mann-Kendall tests.*

INTRODUCTION

The impacts of anthropogenic activities on the earth atmosphere and its systems have been engaging attention of planners, governments and politicians worldwide. Climate change is one of the key components in the earth system. There are many variables such as temperature, rainfall, atmospheric pressure, humidity that constitute weather and climate. Climate is usually defined as the average weather. In board sense, it is the statistical description in term ofthe mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years (IPCC, 2007).Globalwarming has caused the problem of climate change whichisdrastically accelerated much faster in last few decades. Climate is warmed up of 0.89^{0}C (0.69 to 1.08) over the period 1901-2012, whereas in last 25 years it has increased with a rate of 0.18 % per decade in the last 25 years, which is mainly attributed to anthropogenic activities(Grover, 2013; IPCC, 2013,). Climate Change and climate variability areassociated with the trends in hydro-climatic variables such as temperature, rainfall, relative humidity, evapotranspiration, runoff, etc. (Birsan et. al., 2005). The assessment of climate change in termof trend detection is generally carried out using historical data (Trenberth et. al., 2007; Sahu, 2007, Sahu and Dev, 2007, Sahu*et. al.,* 2020; 2021a, 2021b, 2022; Adamowski et. al., 2010; Nalley et. al., 2013;Nourani et. al., 2018, Rajani et. al., 2020). The analysis of long term changes in climatic variables is a fundamental task in studies on climate change detection. The understanding of past and recent climate change has received considerable attention through improvements and extensions ofnumerous datasets and more sophisticated data analysis across the globe (Kumar et. al., 2010). Global climatic change may influence long term rainfall pattern impacting the variability of water, along with the danger of increasing occurrences of droughts and floods (Pal and Mishra, 2017). Madhya Pradesh spreads over 30.8 million hectares of land and shares around 6.0 percent of India's population. Around 71.3 percent of the population lives in rural areas as compared to the national and average of 68.8 percent, making the state largely a rural economy. Bundelkhand in Madhya Pradesh is considered as one of most downtrodden and poverty-stricken region in the country. The region comprises of six districts of Madhya Pradesh (Chhatarpur, Tikamgarh, Damoh, Sagar, Datia and Panna) and all of them have their economy predominantly based on rainfed agriculture. Through the Bundelkhand agro-climatic zone is not prone to big natural disaster such as earthquake, cyclone, and flood but is affected by extreme weather events such as hot days, hailstorm, frost, which ultimately upsets the framing in this zone frequently. The monsoon rains are quite crucial and forpast several years, the region has received deficit rains leading to drought particularly for agriculture related activities (Shrivastava et. al., 2020).

A few studies on key aspects of the climate change on rainfall variability studiesin India have been carried out by various researcher viz., Yadav et. al., 2019, Shrivastava et. al., 2020; Panda et. al., 2019, Thakural et. al., 2018; Naidu et. al., 2016; Rajani et. al., 2020; Chinchorkar, et. al, 2016, Singh et. al., 2013; Modarres and da Silva, 2007; Kumar and Gautam, 2014; Sinha and Shrivastava, 2000; Seo and Ummenhofer, 2017. The trend analysis ofrainfall (Partal and Kahya, 2006; Addisu, et. al., 2015; Neil and Notodiputro, 2016; Singh and Shivastava, 2016) and other climatic variables on deferent spatial scales will help in the construction offuture climate scenarios.

Hence the purpose of this study is to investigate the variability of the rainfall pattern of Chhatarpur district Bundelkhand region of Madhya Pradesh, India. Seasonal trend of the rainfall pattern has been investigated on inter-annual basis and the fluctuations have been calculated on monthly basis with major focus on monsoon season (June- September). This includes anunderstanding of the area's rainfall trend and its variability. Understanding the uncertainties associated with rainfall patterns will provide a knowledge base for better management of water resources development, Groundwater recharge, Agricultural and irrigation and other water related activities in the associated area.

LOCATION OF THE STUDY AREA

Chattarpur district located at 24.06° & 25.20°N 78.59° & 80.26° E respectively. It has an average elevation of 305 meters (1,000 feet). The district has an area of 8,687 km². Chhatarpur District is bounded by Uttar Pradesh State to the north, and the Madhya Pradesh districts of Panna to the east, Damoh to the south, Sagar to the southwest, and Tikamgarh to the west. Chhatarpur District is part of Sagar Division. The District Chhatarpur was known after the name of the great warrior of the region Maharaja

Chhatrasal. It is 133 km. from Jhansi in Uttar Pradesh, 233 km. from Gwalior 162 km.from Sagar, 70 km. from Panna and 343 km. from Bhopal via road and 287 Km. via Air and road (Chhatarpur –khajuraho - Bhopal) in Madhya Pradesh.

OBJECTIVE OF THE STUDY

- To collect the rainfall data during the period of 1901-2019 from IMD and Local Land Record Department Chhatarpur district (M.P.) and determine various statistical parameters such as Mean, Median, Mode, Coefficient of Dispersion, and Co-efficient of Skewness.
- To determine regression model and Time series analysis techniques for Climate Change Impact study on Rainfall Patterns in the region.
- To identify of Mann Kendall test and Sens's slope methods for Climate Change Impact study on Rainfall Patterns in the region.

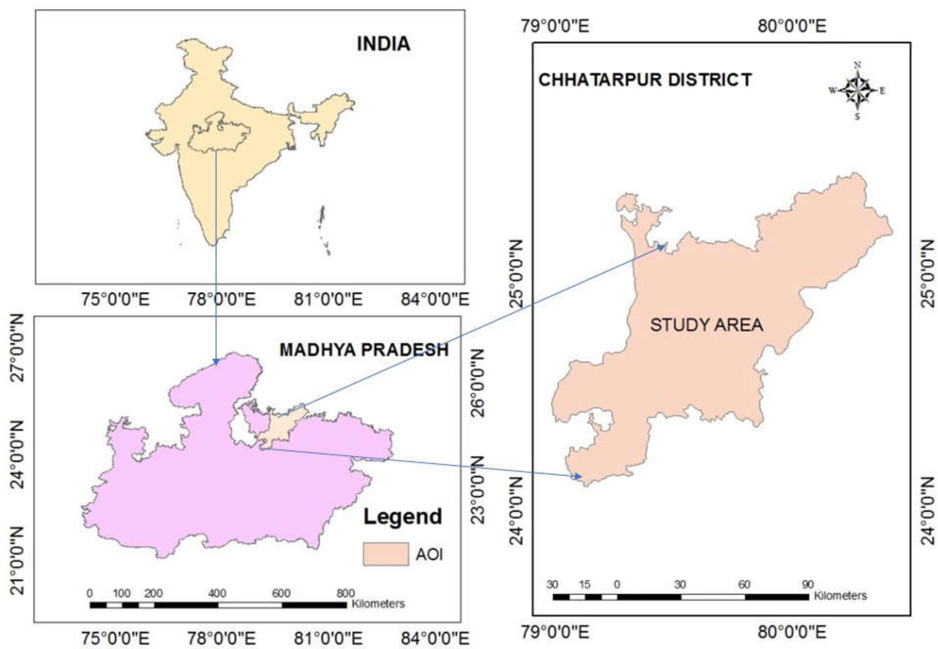

Figure 1: Location Map of the Study Area

MATERIALS AND METHODS

In the present study, records on rainfall data have been collected from the IMD, New Delhi and Land Record Department District Chhatarpur, Madhya Pradeshand were further used for analysis. Moreover, the rainfall records at Chhatarpur station were selected for 119thyears (1901-1919) having continues rainfall data. The meteorological station Chhatarpur district Madhya Pradesh used in this study of changes in rainfall pattern at deferent time scales, a year was divided into three parts of study:

1. Monthly rainfall data analysis from January to December.
2. Annual rainfall data analysis 1901 to 2019.
3. Seasonal rainfall data analysis from spring to winter.

For evaluation of trend in rainfall, daily data have been used to from monthly totals. Monthly data of rainfall were further used to compute the seasonal and annual time series, which were in term used for the investigation of trend on seasonal and annual time scale.

Trends in data can be identified by using nonparametric methods arewidely used. The nonparametric methods do not require normality of time series and also are less sensitive to outliers and missing values. The nonparametric methods are extensively used for analyzing the trends in several hydrologic series namely rainfall,temperature,pan evaporation, wind speed etc. (Chattopadhay et. al., 2011; Dinpanshoh et. al., 2011; Fu et. al., 2004; Hirsch et. al., 1982; Jhajharia and Singh, 2011; Jhjharia et. al., 2009, 2011; Tebakari et. al., 2005; Yu et. al., 1993). The present study analyses the trends of rainfall series of each individual station using Mann-Kendall test and Sens's estimator of slope (non parametric) for climate change detection.

Mann-Kendall's Test

The M-K test is a statistical non -parametric test widely used for trend analysis in climatological and hydrological time series data. The test was suggested by Mann (1945) and has been extensively used with environmental time series. There are two advantages to usethis test. First, it is a non- parametric test and does not require the data to be normally distributed. Second, the test has low sensitivity to abrupt breaks due to inhomogeneous time series. According to this test, the null hypothesis H0 assumes that there is no trend (The data is independent and randomly ordered). This is tested against the alternative hypothesis H1, which assumed that there is trend. The M- K statistics computed asfollows:

$$S=\sum_{k=1}^{n-1}\sum_{j=k+1}^{n} \operatorname{sgn}(xj - xk)$$

The trend test is applied to a time X_k, which is ranked from k=1,2,3,…..,n-1, which is ranked from j= i+1, i+2, i+3,….n. Each of the data points x_j is taken as a reference point,

$$\operatorname{sgn}(xj - xk) = \begin{cases} 1 & \text{if } xj - xk > 0 \\ 0 & \text{if } xj - xk = 0 \\ -1 & \text{if } xj - xk < 0 \end{cases}$$

This particular test has been calculated using XLSTAT 2017 software. A very high positive value of S is an indicator of an increasing trend and a very low negative value indicates a decreasing trend. The presence of a statistically significant trend is evaluated using Z value.

Sen's Slope Estimator Test

The magnitude of a trend in a time series can be determined using a nonparametric method known as Sen's estimator (Sen, 1968). To estimate the true slope of an existing trend such as amount of change per year, Sen's nonparametric method is usedand the test has been performed using XLSTAT 2017 software. A positive value of Sen's slope indicates an upward or increasing trends and a negative value gives a downward or decreasing trend in the time series.

RESULT AND DISCUSSION

Trend analysis in various study shows that there are generally nonparametric (Hollander and Wolfe, 1973) methods were used, M-K test (Mann, 1945; Kendall, 1975) is one of the best methods among them, which is preferred byvarious researcher (Jain and Kumar, 2012). The descriptive statistics of rainfall such as the maximum and minimum, mean, median, Standard deviation, coefficient of variation, kurtosis, and skewness are discussed (Table1).Monthly rainfall trends for Chhatarpur district over the last one hundred nineteen years are comprises months of January to May and September to December are shows significantly decreasing trends of the area. Only one significant increasing trend appears in the area towards June-August (Fig. 2). The yearly rainfall and trend detection of the annual rainfall of the study area shows that during the year of 1901 to 2019 and also given linear regression equation (Fig. 3). The average rainfall of the Chhatarpur district has been calculated and found to be 1121.605 mm.

The departure from the average rainfall of the study area under investigation is given in the graph (Fig. 4) showing the departure from average rainfall shows that during the year of 1901 to 2019.

Hence, these year rainfall data above the average line which years were favourable for ground water recharge of the area and these years rainfall data found below line of average were not favorable for ground water recharge of the area.

Table 1: Statistical analysis of rainfall data Chhatarpur, Madhya Pradesh (1901-2019)

Month/ Seasons	Maximum	Minimum	Mean	Median	CD	SD	CV (%)	Skewness	Kurtosis
January	118.602	0.1	20.153	13.717	1.0651	21.604	106.5076	1.6320	3.4540
February	71.513	0.02	13.972	8.95	1.1648	16.278	116.4794	1.7120	
March	55.462	0.01	10.514	5.32	1.2542	13.194	125.4183	1.6220	2.1970
April	35.6	0.01	4.486	1.791	1.3183	5.906	131.8304	2.0540	5.9590
May	39.7	0.02	5.336	2.88	1.2826	6.826	128.2601	2.6320	9.3150
June	322	10.056	106.928	85.683	0.6846	73.669	68.4650	0.9670	0.3960
July	741.637	78.042	345.041	338.05	0.386	133.305	38.5960	0.3230	-0.1640
August	826.691	127.502	383.711	378.238	0.3665	140.189	36.6456	0.4260	0.1030
September	528.1	3.779	180.899	174.127	0.5431	96.118	54.3079	0.6710	0.6010
October	159.8	0.28	27,137	15.621	1.242	33.557	124.2024	1.7490	3.2570
November	118.428	0.1	14.605	0.591	1.8052	26.565	180.5178	2.0170	3.1330
December	75.593	0.01	8.823	2.447	1.5398	13.221	153.9832	2.3880	6.9870
Spring	106	1.0	20.337	17.192	0.8864	18.014	88.6429	1.9700	5.5630
Summer	1350.4	345.414	835.68	839.899	0.2648	221.217	26.4759	0.0600	-0.4320
Autumn	555.394	9.455	222.64	213.176	0.4983	108.998	49.8345	0.5410	0.0610
Winter	168.3	0.1	42.948	37.184	0.7318	31.352	4983.4490	1.1820	1.9080
Annual	1682.096	575.2	1121.605	1123.193	0.2295	256.4223	22.9476	-0.0300	-0.7530

Table 2: Sen's estimator of slope for monthly, seasonal and annual rainfall data of Chhatarpur, Madhya Pradesh (1901-2019)

S. No.	Month/Seasons	'Z' Values	Sen's Slope
1.	January	-.77	-.014
2.	February	+.59	+.006
3.	March	-.03	.000
4.	April	-.09	-.001
5.	May	+2.01	+.022
6.	June	+4.27	+.730
7.	July	+.59	+.183
8.	August	+0.3	+.069
9.	September	-4.13	-1.158
10.	October	-2.62	-.302
11.	November	-3.15	-.005
12.	December	+.05	.000
13.	Spring	+2.71	+.131
14.	Summer	+2.13	+2.61
15.	Autumn	-2.58	-2.582
16.	Winter	-3.27	-.538
17.	Annual	+2.02	+3.236

The Mann-Kendal (MK) test has been employed by a number of researchers (Yu et.al., 1993, Singh et. al. 2008a, b). The MK method used for a trend in a time series without specifying whether the trend is linear or non linear. The MK test was also applied the present study. The MK test result fined by the using Programme 'AUTO_MK_Sen.exe'. This programme developed for calculate Sen's Slope, Mann-Kendall Test by Dr. Vijay Kumar, Scientist, NIH, Roorkee.The Mann-Kendall (MK) test has been used for Identification of the statistical significance of trend at a confidence interval of 95%. The Sen's slope estimator was then applied to estimate the magnitude of the trend over the study period (Table 2). The Sen's slope was applied to verify the outcome of the simple regression analysis.

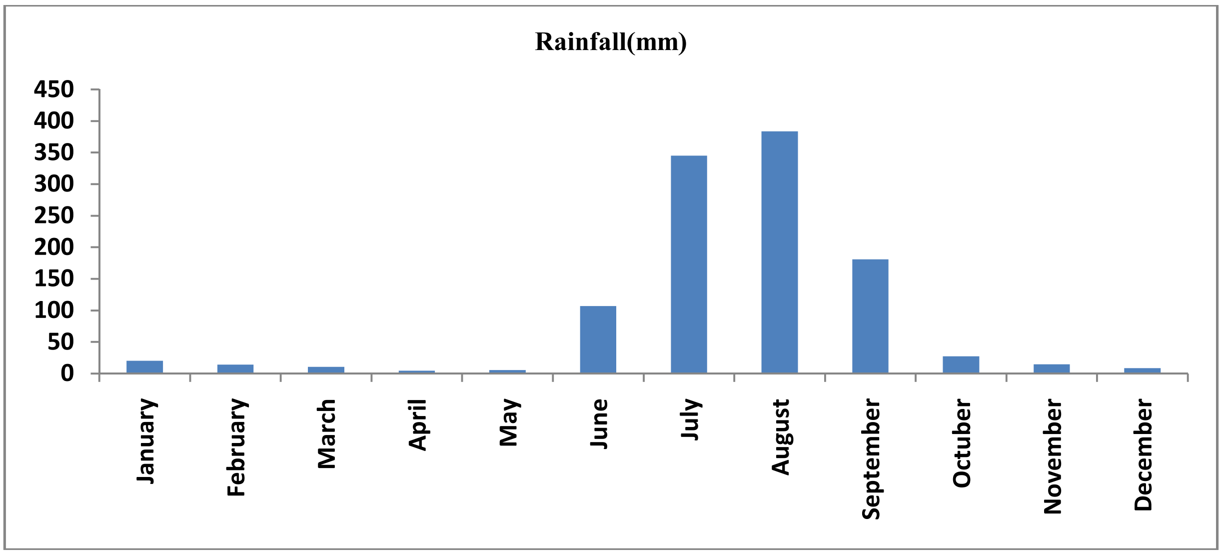

Figure 2: Mean Monthly Rainfall data of Chhatarpur, Madhya Pradesh (1901-2019).

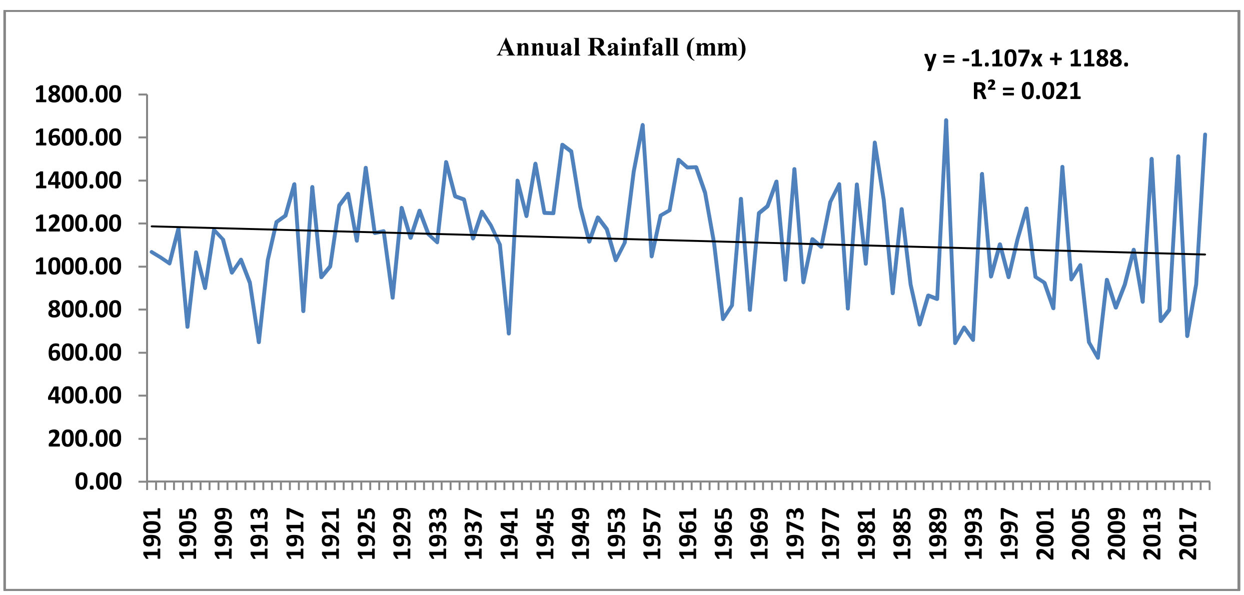

Figure 3: Average annual rainfall data of Chhatarpur, Madhya Pradesh (1901-2019)

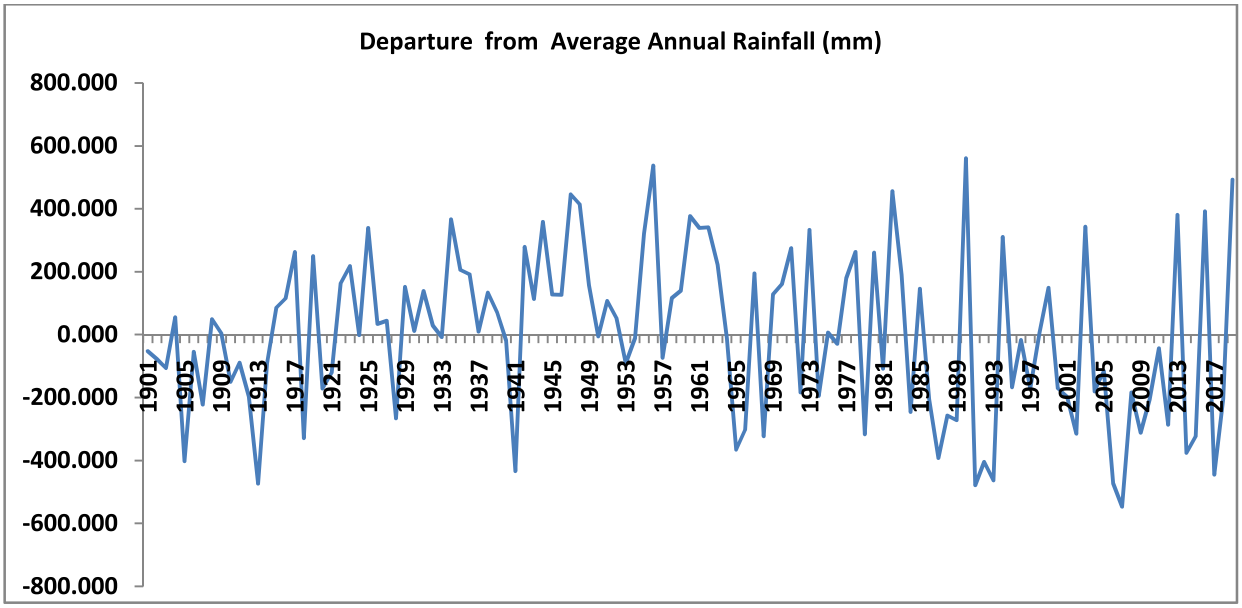

Figure 4: Departure from average Rainfall data of Chhatarpur, Madhya Pradesh (1901-2019)

CONCLUSION

The detection of trends and magnitude of variations due to climatic changes in hydro-climatic data particularly rainfall/precipitation and stream flow is essential for the assessment impacts of climate variability and change on the water resources of the area. The present study is based on the analysis of trend in rainfall data using parametric (linear regression) and nonparametric (Mann –Kendall test and Sen's estimator of slope) methods on seasonal and annual scale for the Chhatarpur district Madhya Pradesh, India. The analysis shows these year rainfall data above the average line which years were favourable for ground water recharge of the area and these years rainfall data found below line of average were not favorable for ground water recharge of the area and also indicate for climate change impact of rainfall of the area.

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REFERENCES

1. Adamowski, J., Adamowski, K. and Bougadis, J., (2010). Influence of trend on short duration design storms, *Water Res. Manage.*, 24, 401-413.
2. Addisu, S., Selassie, Y.G., Fissha, G. and Gedif, B. (2015). Time series trend analysis of temperature and rainfall in Lake Tana sub-basin, Ethiopia. Environmental Systems Research, 4(1), 25.
3. Birsan, M. V., Molnar, P., Burlando, P. and Pfaundler, M., (2005). Streamflow trends in Switzerland, *J. Hydrol.*, 314, 1-4, 312-329.
4. Chattopadhyay S. Jhajharia D, Chatopadhyay G. (2011). Univariate modeling of monthly maximum temperature time series over North East India: neural network versus Yule-walker

equation based approached. Meteorolog Appl 18, 70-82.

5. Chinchorkar, S. S., Trivedi, M. M., Patel, G. R., Paradava, D. M. and Ram, B., (2016). Evaluation of Temperature and Rainfall Trends using Mann-Kendall Test in Saurashtra Region (Junagadh) of Gujarat, India, *Advances in Life Sci.*, 5, 12, 4935-4948.

6. Dinpashon Y. Jhajharia D., Fakheri-Fard A, Singh V.P., Kahya E. (2011). Trends in reference evapotranspiration over Iran. J. Hydrol, 399, 422-433.

7. Fu G, Chen S., Liu C., Shepard D. (2004). Hydro-climatic trends of the Yellowbasin for the last 50 years. Clim. Change 65, 149-178.

8. Grover, V. I., (2013), Impact of Climate Change on Water and Health, CRC Press, NY, p428.

9. Hirsch RM, Slack JR, Slack RA. (1982). Techniques of trend analysis for monthly water quality data Water Resource Res. 18(1), 107-121.

10. Hollander, M. and Wolfe, D.A. (1973). Nonparametric Statistical, Methods. New York: John Wiley & Sons.

11. IPCC (2007). Climate change impacts, adaptation and vulnerability working Group II Contribution to the Intergovernmental Panel on Climate Change, Fourth assessment report, Summary for Policymakers, 23.

12. IPCC (2013). Climate Change 2013 - The Physical Science Basis, Cambridge.

13. Jain, S.K. and Kumar, V. (2012). Trend analysis of rainfall and temperature data for India, Current Science, 102, 37–42.

14. Jhajharia D, Shrivastava SK, Sarkar S (2009). Temporal characteristics of pan evaporation trend under the humid conditions of Northeast India. Int. J. Climatol. 31(9), 1353-1367.

15. Jhajharia D, Singh VP (2011.) Trends in temperature, diurnal temperature range and sunshine duration in Northern India. Int J Climatol, 31(9), 1353–1367

16. Kendall, M.G. (1975). Rank Correlation Methods, 4th edition. London, UK: Charles Griffin.

17. Kumar, V., Jain, S.K. and Singh, Y. (2010). Analysis of long term rainfall trends in India. Hydrological Sciences Journal, 55(4), 484–496.

18. Kumar, R. and Gautam, H.R. (2014). Climate change and its impact on agricultural productivity in India, Journal of Climatology and Weather Forecasting, 2, 109,

19. Mann, H.B. (1945). Non-parametric tests against trend. Econometrica, 13, 163–171.

20. Modarres, R. and da Silva, V.P. (2007).Rainfall trends in arid and semi-arid regions of Iran. Journal of Arid Environments, 70, 344–355.

21. Naidu, T.G., Ganga Raju, M. Lalitha K. and Hema Malini B.(2016). Climate change assessment through Temperature and rainfall variability analysis in adilabad district of Telengana state India, the Indian Geographical journal, 1(2), pp. 133-146.

22. Nalley, D., Adamowski, J., Khalil, B. and Ozga-Zielinski, B., (2013). Trend detection in surface air temperature in Ontario and Quebec, Canada during 1967-2006 using the discrete wavelet transforms, *Atmos. Res.*, 132, 375-398.

23. Neil, M.N. and Notodiputro, K.A. (2016). Trend and pattern classification of surface air temperature change in the Arctic region. Atmospheric Science Letters, 17, 378–383.

24. Nourani, V., Mehr, A. D. and Azad, N. (2018).Trend analysis of hydroclimatological variables in Urmia lake basin using hybrid wavelet Mann-Kendall and Şen tests, *Environ. Earth Sci.*, 77(5),207.

25. Pal, A.B. and Mishra, P.K. (2017). Trend analysis of rainfall, temperature and runoff data: a case study of Rangoon watershed in Nepal. International Journal of Students' Research in Technology & Management, 5(3), 21–38.

26. Panda, A. and Sahu, N. (2019).Trend analysis of seasonal rainfall and tempreraturе pattern in Kalahandi, Bolngirand Koraput Districts of Udisha, India, Atmos. Sci. Lett. 20, e932.

27. Partal, T. and Kahya, E. (2006). Trend analysis in Turkish precipitation data, *Hydrol. Processes*, 20(9), 2011-2026.

28. Rajani, N.V. Tiwari, M. K., Chinchorkar, S. S. (2020). Longterm analysis of rainfall using hybrid Discrete Wavelet transform (DWT) based Mann –Kendall test in central Gujrat region, India, Mausam 71(2), 209-224.

29. Sahu, OP (2007). Quantitative and qualitative investigation of shallow Hydrogeological regime of Nimni River Basin, Chhatarpur district Madhya Pradesh, M.Phil. thesis Vikram University Ujjain (M.P.), India, pp.94.

30. Sahu, OP and P Dev (2007). Role of rain water phenomena in recharge of ground water resource in Chhatarpur area Madhya Pradesh, proc. Ground water national seminar on Agriculture and Rural Drinking Water, organized by AICGWBOA, India, Vol.1, pp. 364-371.

31. Sahu, O.P., Sahu, Pitambra and Jain, Pradeep k. (2020). Climate change impact studies on rainfall patterns for past and present century -a case study, Int. National Jour. of global sci. res. 7(1), 1109-1131.

32. Sahu, OP, Sahu, P and Jain, Pk (2021a). Rainfall data analysis and environmental impact study of Chhatarpur district Central India, bul. of pure and appl. Sci. Geol. 40F (2), 244-253.

33. Sahu, OP, Sahu, P and Jain, Pk (2021b). Rainfall trend and climate change scenario of Panna district Madhya Pradesh, India, Proc. Int. National Conf. on Ground Water (ICGW-2021). Edit. Dr. Anjali Singh and Dr. Ankush Shrivastava, Department of Geology, MLS University, Udaipur Rajashthan, India, pp. 22-38.

34. Sahu, OP., Sahu, P, Jain, PK, Baburao GR (2022). Climate change impact studies on historical rainfall records: a case studies of Dindori district, Madhya Pradesh, India, bul. of pure and appl. Sci. Geol. 41F (1), 90-102.

35. Sen, P.K. (1968). Estimates of the regression coefficient based on Kendall's tau. Journal of the American Statistical Association, 63,1379–1389.

36. Seo, H. and Ummenhofer, C. (2017). Intra-seasonal rainfall variability in the Bay of Bengal during the summer monsoon: coupling with the ocean and modulation by the Indian Ocean dipole. Atmospheric Science Letters, 18, 88–95.

37. Shrivastava, A.K. Yogranjan and Bal, L.M. (2020). Variability of extreme weather events and its impact on crop yield in Bundelkhand Agroclimatic Zone of Madhya Pradesh, mausam, 71(2), 275-284.

38. Singh, O., Arya, P. and Chaudhary, B.S. (2013).On rising temperature trends at Dehradun in Doon valley of Uttarakhand, India. Journal of Earth System Science, 122, 613–622.

39. Singh P, Kumarm V, Thomas T, Arora M. (2008a). Change in rainfall and relative humidity indifferent river basins in the northwest and central India. Hydrol Process, 22, 2982–2992.

40. Singh P, Kumar V, Thomas T, Arora M. (2008b). Basin-wide assessment of temperature trends in the northwest and central India. Hydrol Sci J, 53(2), 421–433.

41. Sinha, K.C. and Srivastava, A.K. (2000) Is there any change in extreme events like heavy rainfall? Current Science, 79, 155–158.

42. Tebakari T, Yoshitani J, Suvanpiomol C. (2005). Time-space trend analysis in pan evaporation kingdom of Thailand. J Hydrol Eng, 10(3), 205–215.

43. Thakral, L.N., Jain, S.K. and Ahmad, T. (2018). The impact of Climate Change on Rainfall Variability: a Study in Central Himalayas, eds V.P. Singh et. al. Climate Change Impacts, Water Science and Technology library 82, 181-192.

44. Trenberth, K. E., Jones, P. D., Ambenje, P., Bojariu, R., Easterling, D., Klein Tank, A., Parker, D., Rahimzadeh, F., Renwick, J. A., Rusticucci, M., Soden, B. and Zhai, P., (2007). Observations: Surface and atmospheric climate change, In: Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 235-336.

45. Yadav, Seema, Bhattacharya, P., and Shrivastava, Kuldeep. (2019).Analyzing long term seasonal and annual trends for Precipitation and tempreraturе in Central India, mausam, 70(3), 523-532.

46. Yu YS, Zou S, Whittemore D. (1993). Non-Parametric trend analysis of water quality data of riversin Kansas. J Hydrol, 150, 61–80.

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