Temporal Rainfall Variabilityand Its Correlation with Temperature over Ranchi, Jharkhand

Abha Sinha, Anjani Kumari, Somnath Mahapatra, H.P. Singh, Birendra Bharti

ABSTRACT: The extent to which rainfall amount varies across an area (spatial) or through time (temporal) is an important characteristic to determine the climate of an area. The discipline that covers this area in Meteorology/Climatology is known as "Rainfall variability". It is of two types: Areal (Spatial) and Temporal. The temporal variability of rainfall means variation of rainfall as time varies but the area of the location remains the same. The temporal variability of rainfall of a place helps in knowing the rainfall variability with time. Rainfall variability plays an important role in understanding climate change. In this fast growing world, urbanization and industrialization has led to the problem of global warming. As a result of this, there has been a drift rise in temperature. The present research work was taken over to analyze the temporal trend of Rainfall over Ranchi during 1975-2017 and to study its correlation with temperature over Ranchi, Jharkhand during 1975-2009. To analyze the trend in rainfall over Ranchi, rainfall data from 1975-2017 was studied. The annual rainfall ranged from a minimum of 734.6 mm to a highest of 1771.335 mm. The mean, median, coefficient of variance and standard deviation was also found on the monthly, seasonal and annual basis. Through time series graphs of rainfall, a positive trend is detected in summer season while annual, winter and southwest monsoon rainfall appeared as a negative trend. On the other hand, by utilizing non-parametric tests such as Mann-Kendall trend test and Sen Slope, it was found that there was no significant trend at 95% confidence limit in any case. Through the study, it was found that there is a significant correlation of rainfall with temperature over the years 1975-2009. Although it was found to be negative in Summer, Monsoon and Annual data, whereas there was a positive correlation between rainfall and temperature during the winter season.

Keywords: Man-Kendall, Rainfall Variability, Sen Slope, Trend Analysis

I. INRODUCTION

Rainfall is the important meteorological phenomenon and its amount is an important parameter .Rainfall being the most significant part of precipitation is the most important part of hydrological cycle that connects the atmosphere and lithosphere together and is the prime source of the availability of water.

  Abha Sinha*, PG student, DWEM, Central University of Jharkhand, Ranchi, India. Email: abhasinha97@gmail.com
  Anjani Kumari*, M.Tech, DWEM, Central University of Jharkhand, Ranchi, India. Email:anjanikumari.cuj@gmail.com
  Somnath Mahapatra, Scientist-E, Indian Institute of Tropical Meteorology, Pune, India. Email: mahap@tropmet.res.in
  H.P. Singh, Professor, DWEM, Central University of Jharkhand, Ranchi, India. Email: singh.harendra121@gmail.com
  Birendra Bharti, Assistant professor, DWEM, Central University of Jharkhand, Ranchi, India. Email: birendrabhari@gmail.com

In developing countries, like India, Rainfall variability is the major factor influencing the agricultural productivity, depending on rain fed areas .The knowledge of Rainfall variability is of great importance. The extent to which rainfall amount varies across an area or through time is important characteristic to determine the climate of an area. Precipitation and air temperature are other important climatic variables. Precipitation is an important component of rainfall- runoff analysis as well as it influences assessments of drought, flood etc. Researchers have shown that global surface temperature rises at a rate of $0.74 \pm 0.18°C$ over 1906–2005 (IPCC 2007).As per IPCC 2007 there will be reduction of fresh water in future due to severe climate change .It has been forecasted that by the end of the twenty first century rainfall will increase up to 15-30%. By, Bureau (2004), and Dorde et al., (2009) the world population of 60% will be residing in cities by 2030. Due to urbanization there has been a considerable change in land use and land pattern. Urbanization changes the natural land to artificial land and therefore changes the temperature and moisture of the surface (Hung et al 2006), thus affecting the availability of water resources. Tigga and Malini (2011)did a study on "Temperature Trends in Ranchi City , Jharkhand" over the time course of 1901-2010 using linear and moving average .The study of linear trend increasing trend in average and maximum temperatures and decreasing trends in minimum temperature. They observed that these periods were closely associated with the period of industrialization and phase of urbanization. The analysis of temperature on monthly and seasonal basis showed that there was sharp decline in minimum temperature throughout winter season and particularly in the coldest month (January) than any other seasons or month. The availability of adequate or satisfactory freshwater of felicitous quality has become a limiting factor for the development worldwide. In arid and semiarid regions of the world, water scarcity and low per capita water allocation has always been a overriding challenge. The situation has further exacerbated due to increase in population and the associated expansion of urbanization and economic activities, all of which demand additional water and thus impose a cosmic pressure on the insufficient water resources. In Ranchi district the river system is comprised of Subarnarekha River. Apart from housing a hydel project in Ranchi, the river also serves as a main source for municipal water supply and industries. According to India Water Portal, The pitiful state of Subarnarekha stands testimony to the changing times. The present study aims to study the monthly, seasonal and annual rainfall trends in Ranchi (1975-2017), the trend analysis of rainfall in Ranchi (1975-2017), the trend analysis of temperature in Ranchi (1975-2009), the correlation between the seasonal and annual rainfall and temperature in Ranchi (1975-2009).

II. MATERIALS AND METHODS

A. Description of the study area

Ranchi is a district of Jharkhand with its geographical locations as 23°21'-23°87' North latitude and 85°75'-85°87' East longitude. Its elevation is 500 to 700 meter above mean sea level. The municipal area of Ranchi is about 251.75 square miles, or 652.02 km2. Ranchi lies at 23°22′N and 85°20′E near the Tropic of Cancer. The local river system is comprised mainly of The Subarnarekha River and South Koel River. The Subarnarekha river, a rain fed peninsular river originates from Piska More near Ranchi. Ranchi is characterized by subtropical climate wherein the months of March, April and May are referred to as Summer, June, July, August and September are Monsoon months and November, December, January and February are the Winter months. The temperature of Ranchi district ranges from 20˚C to 37˚C during summer and 3˚C to 22˚C during winter. Ranchi has mean rainfall of about 1530 mm. Maximum rainfall of the study region has been observed from June to September which accounts for 90% of the total annual rainfall. The study region receives its rainfall from Southwest monsoon Temperature ranges from 20 ^{0}C to 42 ^{0}C during summer whereas its winter temperature ranges between 0°C to 25°C. December and January are generally considered to be the coolest months of the year.
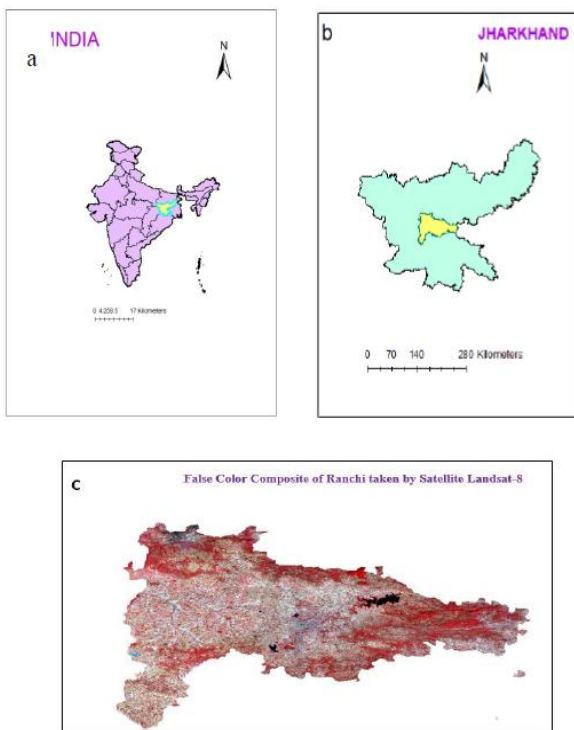

Fig. 1: Layout of study area

B. Data used

The monthly mean precipitation right from 1975 to 2002 has been used as an input parameter for the Rainfall variability and it has been taken from http://www.indiawaterportal.org/met-data/. The data of monthly mean precipitation over the years 2003-2010 has been taken from https://www.indiawaterportal.org/datafinder. The data of monthly mean precipitation over the years 2011 -2017 was taken from http://dsp.imdpune.gov.in/ . The monthly mean temperature over the years 1975-2009 has been taken from http://dsp.imdpune.gov.in/.

C. Methodology

The excel spread sheet and Mann Kendall test has been used for trend analysis and to find the correlation between temperature and rainfall. These methods can be extensively categorized into parametric and non-parametric methods. Parametric method deals with an underlying distribution (typically normal) for the values of interest such as in regression analysis, whereas non-parametric method do not such as Mann –Kendall test.

Mann-Kendall's Trend Test: In the present study, the statistical intent of the trend in monthly, seasonal and annual series was analyzed using the non-parametric Mann-Kendall (MK) test. The Mann-Kendall Trend Test analyzes the sign disparity between earlier and later data points. Every value is compared to its preceding value, thus giving us a total of {n*(n-1)/2} pairs of data.

Here, n= number of observations

MANN KENDALL ANALYSIS

1. 'S' computation

'S' refers to Mann Kendall Statistic.

The initial value of S=0.

If the data value of the succeeding period > the previous data value, S=S+1 and vice versa.

The final result after considering all the data values is the ultimate S value.

i.e., statistically,

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

Here, j>k,

(x_j-x_k) is the difference between two data points.

A high positive S value depicts an rising trend whereas a low negative value depicts a falling trend.

2. To compute the variation of S

$$VAR(S) = \frac{1}{18}[n(n-1)(2n+5) - \sum_{p-1}^{g} t_p(t_p-1)(2t_p+5)]$$

Here, g= number of tied groups (number of data sets that have same value belong to one tied group)

t_p = Number of observations in a group 'p'

For example:

If we have a data sequence in time as {1, 9, 3, 9, 1, 1, 5, 6, 1, 6},

We get, g=4. For the tied value 1, t_1=4.

Similarly, for the tied value 9, t_2=2.

And so on.

2. To compute the Mann-Kendall Test Statistic:

$$Z_{MK} = \frac{S-1}{\sqrt{VAR(S)}} \; if \; S > 0$$

$$= 0 \; if \; S = 0$$

$$= \frac{S+1}{\sqrt{VAR(S)}} \; if \; S < 0$$

ASSUMPTIONS INVOLVED

1. When no trend is present, the observations or data that are obtained over time are equally distributed and are not co-related.
2. The observations collected over time represent the true conditions at any time when the sample was taken.
3. The data collection, handling and measurement methods provide unbiased observations of the real-time conditions.

SEN's Slope

The magnitude of the linear trends present in the hydro-metrological time studies which was evaluated using Theil-Sen slope approach (TSA), (Sen, 1968) and As per the study of Hirsch et al. (1982) the TSA is considered more sound than the least-squares method due to its comparative insensitivity to extreme values and better performance even for normally distributed data. The magnitude of trend in hydro-meteorological data series and all necessary details are available in Lettenmaier et al. Slope (T_i) of all data pairs is computed as (Sen, 1968). In this method, the slopes (T_i) of all data pairs are first calculated by:

$$T_i = \frac{x_j - x_k}{j - k} \quad \text{for i=1,2,3,.......,N}$$

Here, x_j and x_k are data values at a particular time j and k (where, $j > k$) respectively. The median of these N values of T_i is Sen's estimator of slope which can be estimated as:

$$\beta = \begin{cases} T_{\frac{N+1}{2}} & N \text{ is odd} \\ \frac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+2}{2}}\right) & N \text{ is even} \end{cases}$$

In statistics, co-efficient of variation is used to compare the degree of variation from one data series to another. Mathematically, it represents the ratio between standard deviation and mean.

$$Coefficient\ Of\ Variation = \frac{Standard\ Deviation}{Mean} \times 100$$

In this study, rainfall variability has been depicted by co-efficient of variation.

III. RESULTS AND DISCUSSIONS

A. Monthly rainfall trends in Ranchi (1975-2017)

In month of January, there is a gently decreasing trend. But the year 2012 provides an exception with a sudden increase in its rainfall value. In the February and March, the trend is decreasing and the slope is almost twice as that of January. In month of April, the trend is quite similar to the month of January.

In the years 2004 and 2016, a characteristic increase in their rainfall values can be seen. In the month of May, there is no significant change in the trend line. In the years of 2006 and 2009 a sudden increase in rainfall observed and the trend line remains almost parallel to the x-axis. In June, there is significant increase in rainfall over the years, there seems to be a negligent decrease in the trend line. In month of July, 1990 rainfall data proofs an exception and the curve represents a fair decrease in trend. In month of August, the slope is fairly decreasing. In September, the value of this slope is less than the month of August, an overall decrease

in the values of rainfall provide a significant decrease in its trend. In month of October, the years of 2003 and 2014 are exceptions that show a sudden increase in their rainfall, the graph represents that there is a slight increase in trend. In the November month, 2012 curve depicts a sudden increase in the rainfall data, the overall increase in trend remains almost negligible. In month of December, the data shows a number of variations with a high rainfall in 1992, whereas negligible rainfall between the years of 1993 and 1996. Again, the years between 1999 and 2009 show a fall in the rainfall data whereas, there is a sudden increase in 2010 rainfall.

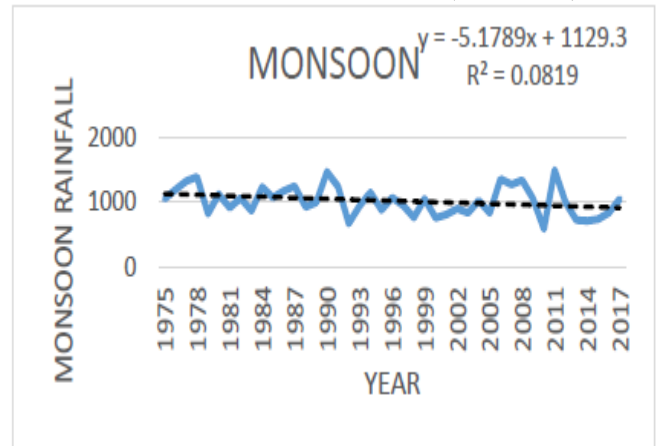### B. Seasonal rainfall trends in Ranchi (1975-2017)
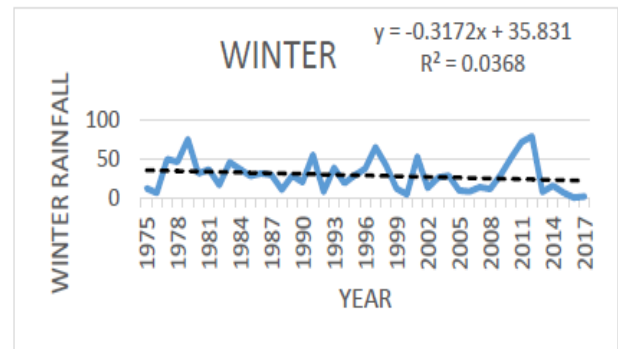

Fig. 2: Monsoon rainfall in Ranchi (1975-2017)
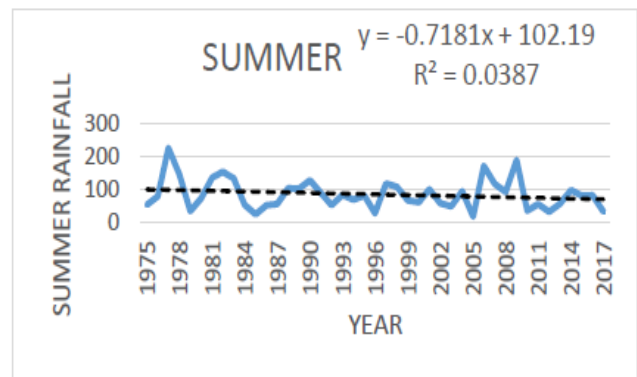

Fig. 3: Winter rainfall in Ranchi (1975-2017).

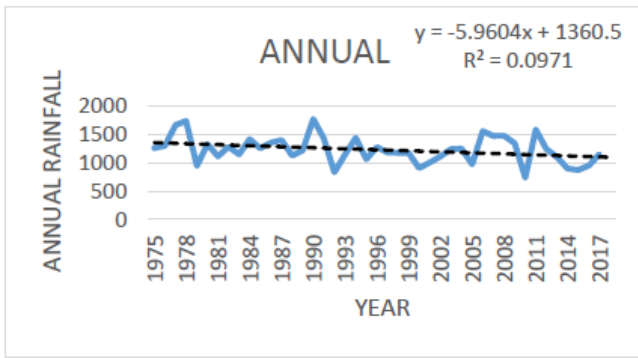**Fig 4: Summer rainfall in Ranchi (1975-2017)**

Fig. 5: Annual rainfall in Ranchi (1975-2017)

As it can be conformed from the above graphs, the maximum rainfall in summer season is 225.959 and the minimum rainfall is 19.7. Here the slope is -0.7181. The square of correlation (R^2) is 0.0387. It is observed from the above graph that there is very less rain in the Summer Season. Moreover there is a decreasing trend in rainfall over the years during this season. The highest value of rainfall in Monsoon season is 1490 and the lowest value of rainfall is 581.8. Here the slope is -5.1789. The square of correlation value is 0.0819. The monsoon season of Ranchi starts from June and ends in September. The district Ranchi receives its rainfall during Monsoon is due to south-west monsoon which accounts for 75% of the annual rainfall with the maximum amount of rainfall in month of July. The southwest monsoon originates from the Indian Ocean and advocates its appearance in Southern Kerala by the end of May.

The onset of monsoon is accompanied by the high speed(30-70 kmph) south-westerly winds and low pressure areas at the advancing edge.The south-west monsoon wind advances over the country in two branches: (1) Arabian Sea and (2) Bay of Bengal. The Bay of Bengal branch marks its set in Assam and firsts covers the north eastern regions and then turns westwards to proceeds into Bihar, Jharkhand and UP. It increses from June to July and starts to weaken in September. In winter season, the maximum rainfall is 79 and the minimum rainfall is 0.2. Here the slope is -0.3172. The square of correlation, i.e., R^2=0.0368. During the month of November, the no. of cyclones formed in the Bay of Bengal is the twice the no. of cyclones formed in Arabian Sea due to low pressure areas and a north-easterly flow of air that picks up moisture .It causes the intense rainfall, Whereas in the months of December to February the rainfall is due to Western disturbances. As it can be seen from figure 4, the maximum Annual rainfall is 1771.335and the minimum rainfall is 734.6. Here the slope is -5.9604. The square of correlation, i.e., R^2=0.0971. As it is visible, there has been a significant decrease in rainfall over the years.

C. To study the trend analysis of temperature in Ranchi 1975-2017)

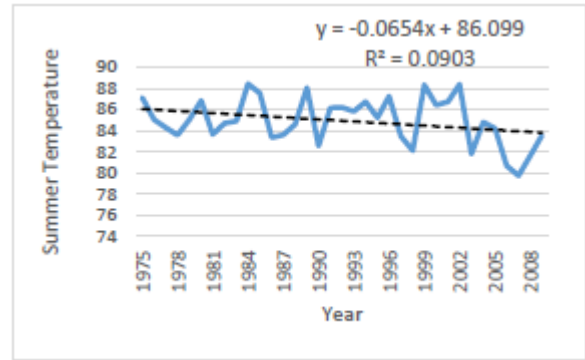The seasonal and annual changes in temperature have been shown in the graphs below:
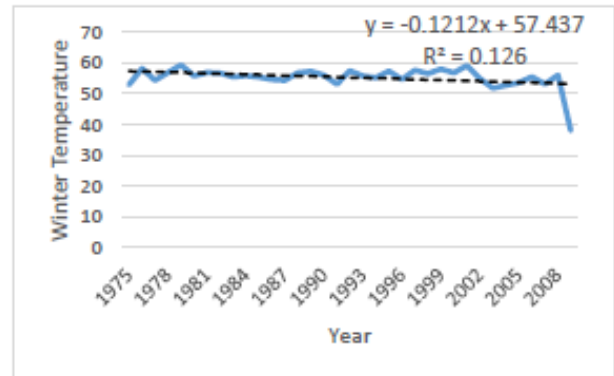

Fig. 6: Summer temperature trend in Ranchi (1975-2009)
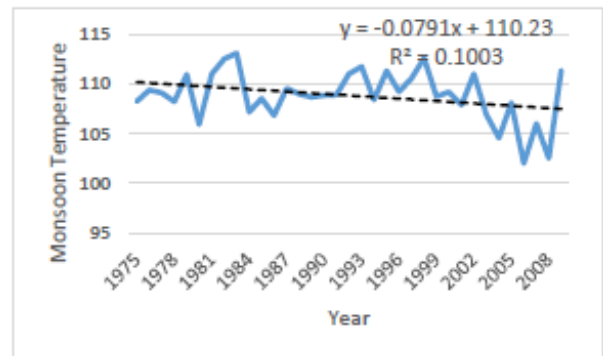

Fig. 7: Winter temperature trend in Ranchi (1975-2009)

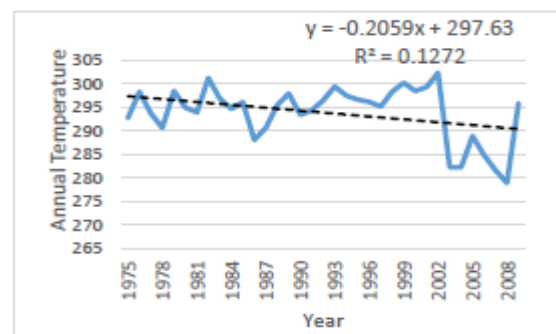**Fig. 8: Monsoon temperature trend in Ranch i(1975-2009)**

Fig.9: Annual temperature trend in Ranchi (1975-2009)

D. Correlation between temperature and rainfall during the summer months.

The value of correlation between total summer temperature and total summer rainfall is -0.43876. This implies that summer temperature is negatively correlated with summer rainfall by a considerable amount.

E. Correlation between temperature and rainfall during the Monsoon months.

The value of correlation between total monsoon temperature and total monsoon rainfall is -0.51095. This implies that monsoon temperature is negatively correlated with monsoon rainfall by a considerable amount.

F. Correlation between temperature and rainfall during the winter months.

The value of correlation between total winter temperature and total winter rainfall is -0.088867. This implies that winter temperature is negatively correlated with winter rainfall by a considerable amount.

G. Annual correlation between temperature and rainfall

The value of correlation between annual temperature and annual rainfall is -0.40334. This implies that annual temperature is negatively correlated with annual rainfall by a considerable amount.

IV. SUMMARY AND CONCLUSIONS

This section describes about the overall analysis of temporal variability of Rainfall and Temperature and there correlation over Ranchi, Jharkhand. The rainfall variability gives an overall insight of temporal variability of rainfall in Ranchi, Jharkhand. Regarding this approach monthly rainfall data had been arranged from India Water Portal right from the year 1975-2010 except for the year 2003 and the years 2011 to 2017 where monthly mean rainfall was arranged from data supply portal of Indian Meteorological Department, Pune. For Temperature, data was taken from the year 1975 – 2009. These has been depicted in the project through the graph plots and through tables. For rainfall through the graph analysis, a positive trend is ascertained in summer season while annual, winter and south-west monsoon rainfall showed a negative trend whereas by Mann-Kendall trend test and Sen Slope, it was found that there was no trend at 95% confidence limit in any case. Through the study it was found that there is a significant correlation of rainfall with temperature over the years 1975-2009 Although it was found to be negative in Summer, Monsoon and Annual data whereas there was a positive correlation between rainfall and temperature during the winter season .

REFERENCES

1. A. Monda., S. Mondal and A. Mukhopadhyay, "Rainfall trend analysis by Mann-Kendall test: a case study of north-eastern part of Cuttack district, Orissa", International Journal of Geology, Earth and Environmental Sciences, vol.2(1), 2012 ,pp.:70-78.
2. A. Dhorde, A. Dhorde and A. Gadgil " Long term temperature trends at four largest cities of India during the twentieth century" Journal of Indian geophysics union Vol.13 No.2, 2009, pp. 85-97.
3. A. Kumari M. , Mayoor, S Mahapatra., H.P.Singh and P.K. Parhi, "Flood Risk Monitoring of Koshi River Basin in North Plains of Bihar State of India, Using Standardized Precipitation Index", International Journal of Advance and Innovative Research, Indian Academicians and Researchers Association, Vol. 5 Issue 3(I),2018.
4. A. Tigga and B.H. Malini, "Temperature trends in Ranchi city, Jharkhand", Punjab Geographer, vol.7, 2011,pp.:21-31.
5. IPCC (2007). "Climate change 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.
6. J.M. Stafford, G. Wendler and J. Curtis, "Temperature and precipitation of Alaska: 50 year trend analysis", Theoretical and Applied Climatology, vol67(1-2),2000,pp.:33-44.
7. K. Daksh., V. Kumari, A. Kumari, M. Mayoor, H.P. Singh and S. Mahapatra "Drought Risk Assessment in the Vidarbha Region of Maharashtra India Using Standardized Precipitation Index", International Journal of Innovative Knowledge Concepts, vol.6,2018.
8. K. Subramanya, Engineering Hydrology, Publisher Tata McGraw Hill, 3rd edition, 2008,pp. 13-20.
9. K.V. Karnewar "Analysis of rainfall trends over Nanded of Maharashtra, India", International Journal of Research,vol.,5(16), 2018,pp:571-581.
10. M. Brunett, l. Buffoni, M. Maugeri And T. Nanni "Precipitation intensity trends in Northern Italy", International Journal Of Climatology, 20, 2000 pp. 1017–1031.
11. M. Brunetti, L. Buffoni , M. Maugeri And T. Nanni, "Trends of Minimum and Maximum Daily Temperatures in Italy from 1865 to 1996", Theoritical andApplied Climatology, vol. 66(1-2),2000,pp.49–60.
12. M. Mayoor, A. Kumari, S. Mahapatra, P. K. Parhi and H. P. Singh , "Comparison of Four Precipitation Based Drought Indices in Marathwada Region of Maharashtra India", International Journal of Advance and Innovative Research, Indian Academicians and Researchers Association, Volume 5 Issue 4(X),2018.
13. P.Guhathakurta andM.Rajeevan "Trends in the rainfall pattern over India" ,The International Journal of Climatology ,vol. 28(11), 2008 pp:1453-1469.
14. P.J. Sharma, V.D. Loliyana, S.R.Resmi, P.V. Timbadiya and P.L. Patel, "Spatiotemporal trends in extreme rainfall and temperature indices over Upper Tapi Basin, India", Theoretical and Applied Climatology, vol.134(3-4), 2018,pp:1329-1354.
15. R.G. Cong and M. Brady "The Interdependence between Rainfall and temperature: Copula Analyses", The Scientific World Journal, 2012
16. R.L. Deka, C. Mahanta, H. Pathak , K.K.Nath and S. Das " Trends and fluctuations of rainfall regime in the Brahmaputra and Barak basins of Assam, India" ,Theoretical and Applied Climatology,vol.114(1-2), 2013,pp.61-71.
17. S. Sharma and P.K. Singh, "Long Term Spatiotemporal Variability in Rainfall Trends over the State of Jharkhand, India", *Climate*, vol.5(1) , 2017.
18. Sen, K. Pranab, "Estimates of regression coefficient based on Kendall's tau", Jiurnal of American Statistical Association, 63(324): 1379-1389, doi:10.2307/2285891, JSTOR 2285891, MR 0258201.
19. S. Shree and M. Kumar,"Analysis of seasonal and annual rainfall trends for Ranchi district, Jharkhand, India", Environmental Earth Sciences,vol. 77, 2018.
20. T. R. Nkuna and J. O. Odiyo, "The relationship between temperature and rainfall variability in the Levubu sub-catchment, South Africa", International Journal of Environmental Science,vol.1,2016,pp:66-75.
21. V. Kumar, S.K. Jain and Y. Singh "Analysis of long-term rainfall trends in India", Hydrological Sciences Journal,vol 55(4), 2010 pp:484-496.
22. Data and information for Ranchi, Jharkhand have been collected from the following links:
a. http://www.imdpune.gov.in/ndc_new/Request.html
b. https://www.indiawaterportal.org/met_data/
c. https://www.indiawaterportal.org/datafinder
23. Rainfall Data Courtesy:
Dr. Manoj Kumar, Head of Department, Centre for Environmental Sciences, Central University of Jharkhand, Ranchi
Mr. Shashank Shree, PhD. Scholar, Centre for Environmental Sciences, Central University of Jharkhand, Ranchi
Miss Poulomi Chakravarty, PhD. Scholar, Centre for Environmental Sciences, Central University of Jharkhand, Ranchi

AUTHORS PROFILE

Abha Sinha is master's student in the department of water engineering and management at Central University of Jharkhand, Brambe Ranchi. She is highly enthusiastic in doing research in the field of hydrology.

Anjani Kumari, M.Tech from Central University of Jharkhand, in Water Engineering and Management, in the year 2018. She has one year experience in teaching at Netaji Subhas Institute of Technology Bihta Patna in the department of civil engineering. She has three numbers of papers in the field of extreme events like flood and drought. She is currently active in research activity including water body depletion. Her areas of interests are extreme event prediction and analysis, river morphology, hydrological modeling planning and management.

Somnath Mahapatra is a scientist, currently working at Indian Institute of Tropical Meteorology, Pune designated at scientist – E grade in Monsoon Mission Division. He has B.Sc degree in physics in 1983 from Ranchi University, Ranchi, M.Sc Tech degree in Applied Geophysics in 1988 and M.Tech degree in Geophysical instrumentation in 1989 from Indian School of Mines Dhanbad. He has successfully published 26 number of research papers in national and international journals. His areas of interest are seasonal and extended range prediction. His research highlights are prediction of seasonal summer monsoon, extreme rainfall event, regional scale hydrological planning, and rainfall over homogenous region of India using dynamical prediction system.

Birendra Bharti is assistant professor in the department of Water Engineering and Management, at Central University of Jharkhand, Brambe Ranchi. He has pursued his PhD from IIT Roorke, M.Tech from Agriculture and Food Engineering Department, Water Resource Development and Management, IIT Kharagpur. He has 11 number of research paper in the field of flood modeling and planning, soil erosion, water conservation and management, river meandering using GIS and Remote Sensing and Spatial distribution of soil loss. His other areas of interests are hydrological Modeling, Remote Sensing and GIS Application in Hydrology and water resource planning and management

H.P. Singh is professor and Head of Department in the department of Water Engineering and Management at Central University of Jharkhand, Brambe Ranchi. He has pursued his PhD from IIT Roorkee. He has M.Tech degree in civil engineering with specialization in Geotechnical Engineering. He has successfully published 20 research articles in international and national referred journals. His research areas are soil liquefaction, ground improvement technique, soil and utilization pond, Ash as construction material and Geosynthetic and reinforced technology.