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Research Article

PRECIPITATION AND TEMPERATURE TREND ANALYSIS OF CHITRAKOOT REGION

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A R T I C L E I N F O

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A B S T R A C T

Study of rainfall and temperature is one of the main topics in taking the decision and planning the development and management of civilization. The nonparametric Mann-Kendall test for trend analysis of climatic variables has been applied to investigate the regular occurrences of drought during the last few decades. The sign test indicates that there is a falling trend in the seasonal rainfall and number of rainy days in a few blocks. However, in our study we have taken the data of rainfall and temperature data from 1990-2014 where used to identify seasonally, variability, trends in Chitrakoot. From analysis of annual seasonal and monthly rainfalls data series it can be concluded that rainfall characteristics of the area is changing even though results of trend analysis of annual rainfall data show no statistically significant trend for period of record considered. The results of the Mann-Kendall trend analyses showed that monthly rainfall and temperature an overall upward and downward trend over the Chitrakoot region. The annual rainfall showed that non-significant decreasing trend at the 95% and 99% confidence levels in the rainfall and temperature over the Chitrakoot region. The results of the Sen's slope trend analyses also showed that monthly rainfall and temperature an overall upward and downward trend and the annual rainfall and temperature showed that non-significant decreasing trend at the 95% and 99% confidence levels over the Chitrakoot region. All the results signify no significant detectable effect of global warming on the annual, monthly and seasonal rainfall trend in Chitrakoot Region. Air pollution and deforestations from urbanization process are some of the factors that affecting the climate change. As the environmental impact from urbanization process maybe quite minimal on this area, this could lead to the least change in rainfall trend.

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INTRODUCTION

Climate of the earth varies across temporal and spatial scales throughout the planet. Large areas of the earth represent variability as a part of their normal climate over both short and long time periods (Houghton *et al*., 1994; Gardner *et al*., 1996). Climatic variability can be described as the annual difference in values of specific climatic variables within averaging periods such as a 30-year period (Melillo *et al*., 1990). These climatic variations will have unexpected consequences with respect to frequency and intensity of precipitation and temperature variability for many regions of the earth.

Air temperature and precipitation are principle element of weather systems, so that examination of their behavior is important for understanding of climate variability because both are highly variable spatially and temporarily at different local, regional and global scales.

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For the prediction of future climate conditions, level of variability of these two weather elements must be examined and understood. Therefore, recently, the focus on climate variability bases mostly on the detection of trends in instrumental records of precipitation and temperature. Several researches of climatic trends have recently been conducted on rainfall and temperature data at different periods of records throughout the world (Tanyaç *et al*., 1997; Kadıoğlu, 1997; Lazaro *et al*., 2001; Turkeş *et al*., 2002; Tosiç & Ukaseviç, 2005; Amban *et al*, 2013; Murat *et al*, 2008).

Climate change is one of many dynamic processes impacting water resources management. Other processes (for example, change in population size and location) economic tinued improvement in the understanding of climate change, its impacts, and the effectiveness of adaptation or mitigation actions requires continued operation of existing long-term monitoring networks and improved sensors deployed in space, in the atmosphere, in the oceans, and on the earth's surface.

The present study focused to evaluate the ground water potential zone of Mandakini river basin part of Madhya

Pradesh and Uttar Pradesh. The Mandakini River originates from Kelhauna hills of Kaimur Group of Vindhyan Super group in Satna (MP) district and meets the river Yamuna after flowing through the Chitrakoot district of Uttar Pradesh.

Total area of the Chitrakoot region is approximately 1821 km². About 675 km² area of the region is the part of Satna district of Madhya Pradesh while the remaining approximately 1146 km² area forms the part of Chitrakoot district in Uttar Pradesh. In the non-monsoon season the Mandakini River becomes almost dry when it reaches at the place called Sati Ansuiya ashram which is a sacred place, a number of springs originate from limestone hillocks to feed the river and convert it into a perennial tributary of the river Yamuna.

Life line of the Chitrakoot region, Mandakini River flows from SW to NE direction and finally joins the Yamuna River. Its place of origin is located at about 80°38" E to $80^0$46" E longitude and 24°54" N to 24°55" N latitude while the place at which the river Mandakini meets Yamuna is located at approximately 81°8" E 81°10" E longitude and 25°25" N to 25°30" N latitude (Fig -1).

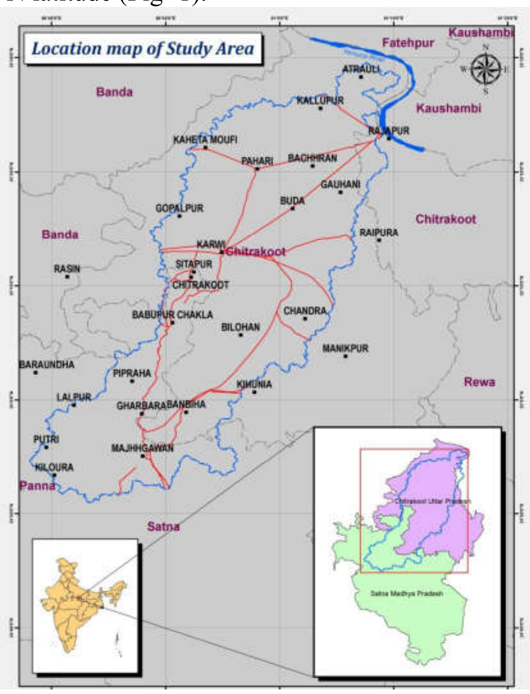

Fig 1 Location of Chitrakoot Region

Mandakini river basin has the unique topography, geology, climate, and agricultural activities in the study area, the major concern and warrants attention of groundwater problems in Bundelkhand region. Hence, the abundance, pathways and sourcing of various ground water potential zones should be systematically looked into for their suitability for water supply of drinking and irrigational purposes.

The aim of this study is to evaluate precipitation and temperature trends in Chitrakoot. To be able achieve our goals we conduct a thorough examination of climatic data from 1990 to 2014 in order to identify seasonality, variability, trends and other characteristics of precipitation and temperature at different time scales. The main purpose of this study is the detection of significant trends or fluctuations in the annual and seasonal climatic conditions.

MATERIALS AND METHODS

Collection of Data

Long-term data records are essential for detecting trends or changes. In this study, the observed daily and monthly rainfall data of Chitrakoot region during the period 1990-2014 (25 years) were obtained from the Indian Meteorological Department (IMD).

Daily rainfall data has been summed into monthly and annual totals. For further analysis, the monthly rainfall data has been categorized according to four seasons. Summer (March-May), spring (June-August), autumn (September-November) and winter periods (December-February).

METHODS

The statistical analysis is used to determine the measure of central tendency (mean) and dispersion (range, standard deviation, skewness, kurtosis and coefficient of variation) for rainfall and temperature data of Chitrakoot region. For identifying the trend in the rainfall data, the statistical analysis of linear regression method is used. The results obtained are further verified by using a non-parametric Mann-Kendall test. Fig.-2 shows the procedure of the analysis being applied in this study.

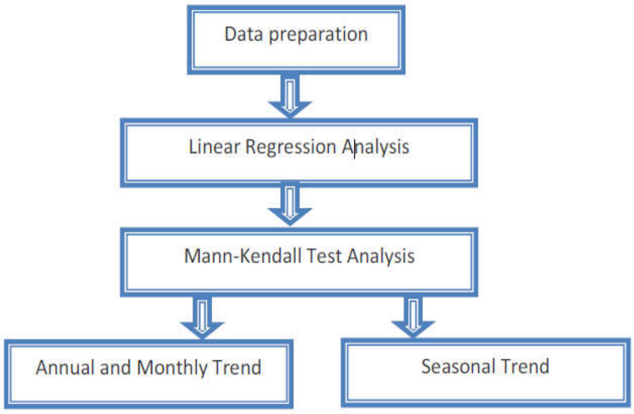

Fig 2 Procedure of the analysis applied in this study

Statistical tools and techniques employed

Range

The range of the distribution was expressed by the limit of the smallest and the largest value of each observation.

$$R = X_{max} - X_{min}$$

Mean

The mean was recorded by summing up all the observation and then dividing by the total number of observations.

$$\overline{X} = \frac{\sum Xi}{n}$$

where,
Σx= Sum of all observations
n = Total number of observations

Standard Deviation

$$\sigma = \sqrt{\frac{(X_i - \overline{X})^2}{n-1}}$$

Coefficient of variation (CV) (%)

Coefficient of variation is standard deviation expressed as percentage of mean

$$\text{CV (\%)} = \frac{\text{SD}}{\text{Mean}} \text{ X } 100$$

Where,
SD = standard deviation, $\overline{X}$ = Mean of parameters

Correlation coefficient analysis

Correlation coefficients were calculated for all possible combinations among the parameters were estimated as given by Searle *et al.* (1961). Correlation between methods x (Mann Kendal trend analysis) and y (Sens Slope trend)

$$r\ (xy) = \frac{\text{Cov (XY)}}{\sigma_x \sigma_y}$$

$$\text{COV(XY)} = \frac{\sum(X_i - \overline{X})(Y_i - \overline{Y})}{n}$$

$$\sigma_x = \sqrt{\frac{(X_i - \overline{X})^2}{n-1}}$$

$$\sigma_y = \sqrt{\frac{(Y_i - \overline{Y})^2}{n-1}}$$

Test the significance of Correlation Coefficient

To test the significance of the correlation coefficient 't' test was used. The usual notation

$$t_{(n-2)} = \frac{|r|\sqrt{n-2}}{\sqrt{(1-r)^2}}$$

Where, n is the number of pairs of observation, r is the correlation coefficient.

Linear Regression

Linear regression is one of the simplest methods to calculate the trend of data in time series. The equation of linear regression line is given by

$$y = a + b\,x$$

Where, x is the explanatory variable and y is the dependent variable. The slope line is *b*, and *a* is the intercept (value of y when x=0). The slope of regression describes the trend whether positive or negative. In this study independent variable, y is rainfall and explanatory variable x is year.

Linear regression requires the assumption of normal distribution. In this case, the null hypothesis is that the slope of the line is zero or there is no trend in the data. The significant of the slope show by the probability value (p-value) of it. In this study, Microsoft Excel was used to calculate the trend lines and statistical values of linear regression analysis. The p-value from the analysis is test for the significant level α=0.05. The value of R-square (R^2), or the square of the correlation coefficient from the regression analysis is used to show how strong the correlation and relationship between the variable x and y. The value is a fraction between 0.0 - 1.0. A R^2 value of 1.0 means that the correlation becomes strong and all points lie on a straight line. On the other hands, when R^2 value of 0.0 means that there is no any correlation and no linear relationship between x and y.

Mann-Kendall (1945) Test

The Mann-Kendall test, is a non-parametric approach, has been widely used for detection of trend in different fields of research including hydrology and climatology (Ampitiyawatta and Guo, 2009). It is used for identifying trends in time series data. Each data value is compared to all subsequent data values. The initial value, S, is assumed to be 0 (no trend). If a data value from a later time period is higher than a data value from an earlier time period, S is incremented by 1. If the data value from later time period is lower than a data value from an earlier time period, S is decremented by 1. The net result of all such increments and decrements yield the final value of S.
Mann Kendall statistic (S) is given by where:

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

Where

$$\text{Sign}(x_j - x_k) = \begin{cases} +1 \text{ jika } (x_j - x_k) > 0 \\ 0 \text{ jika} (x_j - x_k) = 0 \\ -1 \text{jika} (x_j - x_k) < 0 \end{cases}$$

The S statistic, in cases where the sample size n is larger than 10, is approximately normally distributed with the mean equal to 0. The variance statistic is given as:
where t is the extent of any given ties. Then the test statistic, *Zc* is given below:

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

where t is the extent of any given ties. Then the test statistic, *Zc* is given below:

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

The presence of a statistically trend is evaluated using the Z value. A positive (negative) value of Z indicates an upward (downward) trend. The statistic Z has a normal distribution to test for either upward or downward trend at α level of significance (usually 5% with $Z_{0.025}$=1.96), H_0 is reject if the absolute value of Z is greater than $Z_{1-\alpha/2}$ (Rejected H_o: $|Z|>Z_{1-\alpha/2}$) where $Z_{1-\alpha/2}$ is the standard normal deviates and α is the significant level for the test. Probability value (p-value) from two-tailed test using the Z value also can be used to test the significant trend. If the p-value is greater than α, the null hypothesis (H_o: there is no trend in data series) is failed to reject.

Sen's slope estimator test

The magnitude of trend is predicted by the Sen's estimator. Here, the slope (Ti) of all data pairs is computed as (Sen, 1968).

$$T_i = \frac{x_j - x_k}{j - k}$$

For i= 1, 2, 3, ... N

Where, x_j and x_k are considered as data values at time j and k (j>k) correspondingly. The median of these N values of Ti is represented as Sen's estimator of slope which is given as:

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

At the end, Qmed 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 Qi indicates an upward or increasing trend and a negative value of Qi gives a downward or decreasing trend in the time series.

RESULTS AND DISCUSSIONS

Demography of the Study Area

According to the latest census (Census of India, 2011), the total population of Chitrakoot region is 576629. There are around 346 villages and towns in this region. The density and distribution of population increase from South towards north. There are 86041 Household in UP part of the basin as compared to only 15723 households in MP.

In 56 villages of region falling in the state of Madhya Pradesh and only 74231 people reside, while around 502398 people reside in the 290 villages of Uttar Pradesh and hence the demand of water in northern part of the basin is more as compared to the southern part. Chitrakoot, Majhgawan and Pindra are the top three most populous towns in Madhya Pradesh, while Karwi (Chitrakoot Dham), Bhounri, Pahari and Rajapur are the other three populous towns and villages of Uttar Pradesh within the Mandakini River Watershed.

Flora and Fauna

Forest of Chitrakoot is mainly dry deciduous types. The most wood found in this forest is not of good quality and cannot be used for quality wooden furniture. The main tree species found in the district are Dhawa, Dhak, Ankol, Bhavya, Tinsa, Bel, Tendu, Bans, Kasmri, Sakhua, Barun, Mahua, Tilak, Ber, Aonla, Kadamb, Bent, Indrajau, Bijak, and Neebu with other flowering, fruiting and shade giving trees. The other species of plants are Neem, Shisham, Jamun, Palm, Sirar, Semar and Pipal etc.

Besides, several high value medicinal plants are also found in Chitrakoot forests such as *Tinospora cordifolia, Gymnema sylvstre, Achyranthes aspera, Urginea indica, Curculigo orchioides, Dioscorea bulbifera, Desmodium gangeticum, Coccinia grandis, Cordia macleodii,* etc.

The fauna in the present area are mainly herbivorous. In the dense forest some carnivorous animals are also present. Among the animals the common Antelope called Hiran or Mrig are found in the plains. The Nilgai is also found. The Chinkara or Gazelle is common throughout the ravine tracts. The Caracal or Indian lunx is found but rarely, and there are several specimens of jungle cats. The Wolf in the district as a whole is uncommon but is frequently met with in one or two places such as the ravines at Ingua Mau in Tahsil Baberu.

The Fox or Lomari the Gidar or Jackal, the Boar or Jangali Suar are ubiquitous and the striped Hyaena is found in most places. Sambar and Black Buck grows to a good size, but is decreasing in number, while Cheetal are less common. There are few four-horned Antelopes. Here, Porcupines and Monkeys are abundant. Tigers have become extinct owing to indiscriminate shooting, felling of forests, fire havoc and human interference. Snakes and Scorpions are numerous. Among the birds, Peacocks, Parrots, Crows, Doves and Sparrows are omnipresent. There are numerous fish present in the Mandakini River.

Climate

The climatic condition of this area is tropical. Like most of North India, the year is more or less clearly divided into three seasons; namely the hot season extending roughly from middle February to middle June; the rainy season from middle June to September and the winter from November to middle February. The month of October witness the transition from the rainy to the cold weather.

The wind speed in the region is mostly low (< 2 m/s) in almost all the months. The higher wind speeds are observed during monsoon season (June-July). The predominant wind direction is west to North-West. The weather remains dry for all the seasons except monsoon when the humidity is around 85%. Satna & Chitrakoot districts receive its rainfall from the precipitation of the Arabian Sea monsoon. June to September is the months when most of the rainfall is received. The downpour, as well as the number of rainy days is the maximum during the months of July and August. The average rainfall is about 1100 mm which decreases from east to west. The south-eastern parts have the heaviest rainfall, some places receiving as much as 1350 mm, while the western and north-western parts receive 1000 mm or less rain.

In the study area the temperature ranges from 33ºC to 49ºC during summer season and 10ºC to 27ºC during winter season. May-June is the hottest month with daily maximum temperature of above 46°C while January is coolest with minimum temperature of 5°C.

Rainfall

Annual and Monthly Rainfall Analysis

Fig.-3 & 4 shows the long-term average pattern of the annual rainfall of Chitrakoot region. The annual mean rainfall over Chitrakoot region from 1990 to 2014 is 1096.57 mm. The maximum rainfall was recorded in 1991 (2111 mm) while the minimum rainfall recorded in 2006 (343 mm).

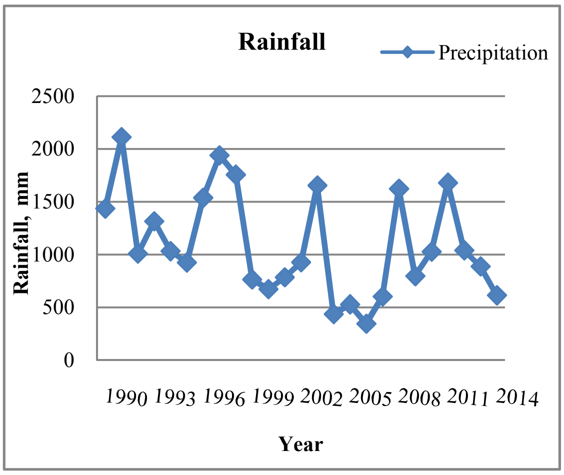

Fig 3 An average annual rainfall in Chitrakoot region from 1990-2014

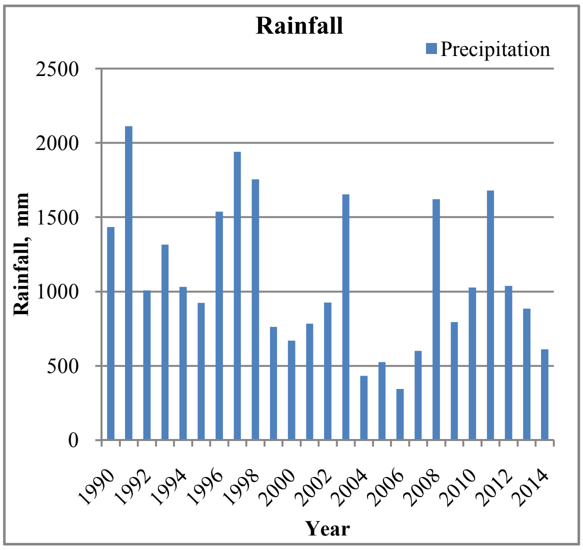

Fig 4 An average annual rainfall in Chitrakoot region from 1990-2014.

Fig.-5 shows the mean monthly rainfall of Chitrakoot region during the period 1990-2014 (25 years). It shows that Chitrakoot experiences pyramidal modal mean monthly rainfall pattern throughout the year. The highest amount of average monthly rainfall was recorded in August (7928.324 mm) and contributes to 28.92% of annual rainfall, followed by July (7841.656 mm) 28.60% and September (6920.619 mm) 25.24%, and the lowest was in May (56.96154 mm) with 0.21% of annual total followed by April (82.59569 mm) 0.31% and November (91.56162 mm) 0.34%.

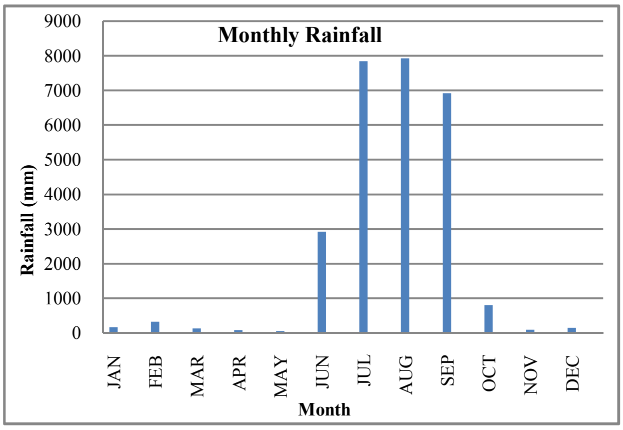

Fig 5 The mean monthly rainfall of Chitrakoot region from 1990-2014

Annual, seasonal and monthly rainfall analysis

The results of statistical analysis of annual and monthly rainfall for Chitrakoot region are presented in Table-1. The annual average rainfall over Chitrakoot region from 1990 to 2014 is 1096.575 mm. spatially, mean annual rainfall of study area is ranged from 343.52 mm in (2006) to 2111.70 mm in (1991). The main rainy season (June to September) contributes 93 % to the annual rainfall totals while rest of the season rainfall contributes 6 to 7 % to the annual rainfall (Table-1). Looking at the amount of rainfall in different seasons, it is evident that all the stations receive the maximum rainfall in monsoon seasons and minimum rainfall in winter season followed by summer season.

According to the results, the Coefficient of Variation (CV) of the monthly rainfall varies between 52.67 % (August) and 359.70 % (April) indicating that there is significant variation in the total amount of rainfall between the months (Table-1). The spring season have represented smaller CV which means that July (58.98 %) and August (52.67 %) are the homogenous month in term of rainfall variation. On the other hand April (359. 70 %) and December (299.84 %) showed the largest CV. The winter and summer depicted similar rainfall pattern reprinting similar variation during the study period. The autumn season showed that small variation as compared to winter and summer.

To test whether the annual, monthly and seasonal rainfall data follow a normal distribution, the skewness and kurtosis were computed. The skewness of annual rainfall is 0.47, this value implies that the distribution of the annual rainfall is slightly skewed to the right or positive skewed. It is inferred that the mass of the distribution is concentrated on the below from the mean rainfall. The monthly rainfall skewness varies between 0.57 to 4.49 mm, implies that the monthly distribution of the rainfall is skewed to the right or positively skewed. Hence it is inferred that the mass of the distribution is concentrated on the below from the mean rainfall.

Kurtosis of annual, monthly and seasonal rainfall varies between -0.83 to 22.56, for the normal curve, the value of kurtosis should be 3, when the value of kurtosis is greater than 3, the curve is more peaked than the normal curve ie. Leptokurtic and when the value of kurtosis is less than 3 the curve is less peaked than the normal curve, ie. Platykurtic.

Seasonal distribution of mean rainfall in study area shown Fig.-6(a-b) the average most rainfall occurs during the spring season (June to Aug) contributes 67. 62 % to the annual rainfall totals and June to September are commonly the month with the highest observed rainfall. There is considerable amount of rainfall in the summer months being around (0.96 %) of annual total in the area. Fig.-7(a-d) represents the total annual rainfall and its trend in the period of under examination. Using a linear regression model, the rate of change is defined by the slope of regression line which in this case is about -22.57 mm/year.

On other hand while winter, autumn and summer and spring season have represented with decreasing trend in the study area. Table-2 provides a description of the applied statistical test procedure. Statistically significant trends are not found for rainfall on annual, seasonal and monthly basis, even, even though there are negative and positive trends for any of period

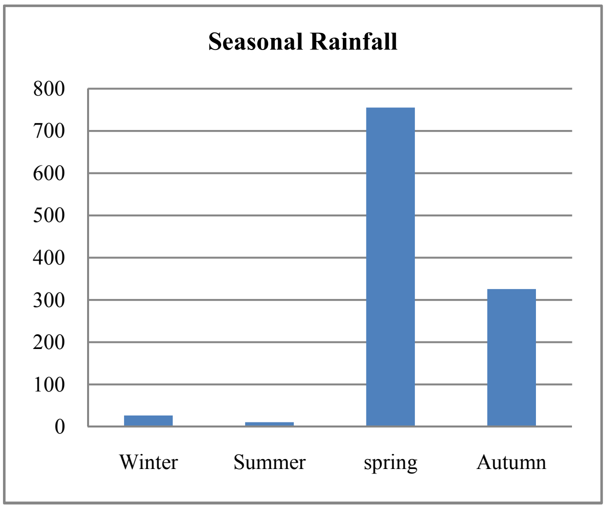

Fig 6(a) Seasonal distribution of mean rainfall in study area

15 year considered. Overall, rainfall trends in is negative but this results is not statistically significant at 95 % confidence limit (MK=-0.23) during the period (table-3). The decrease in annual rainfall observed in the study area caused decreasing by spring rainfall totals, which compensate the slight increase on the other seasons especially autumn months.

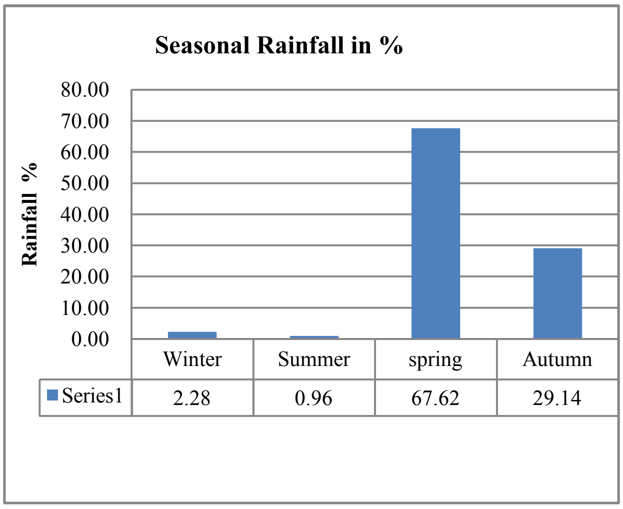

Fig 6 (b) % Seasonal distribution of mean rainfall in study area

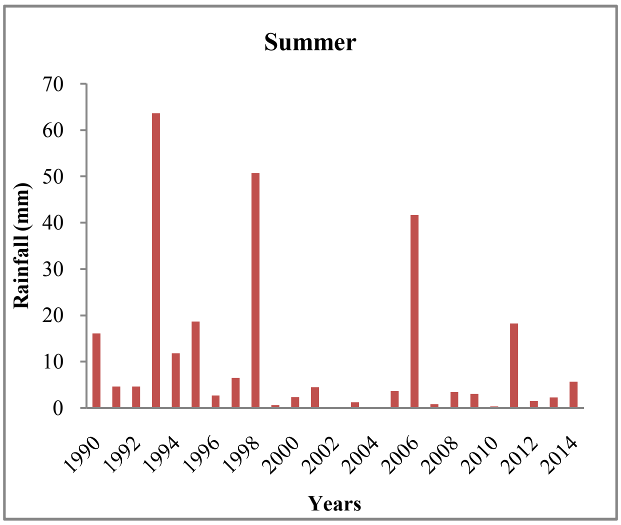

Fig 7(a) Seasonal rainfall series (summer season) for the period of 1990-2014

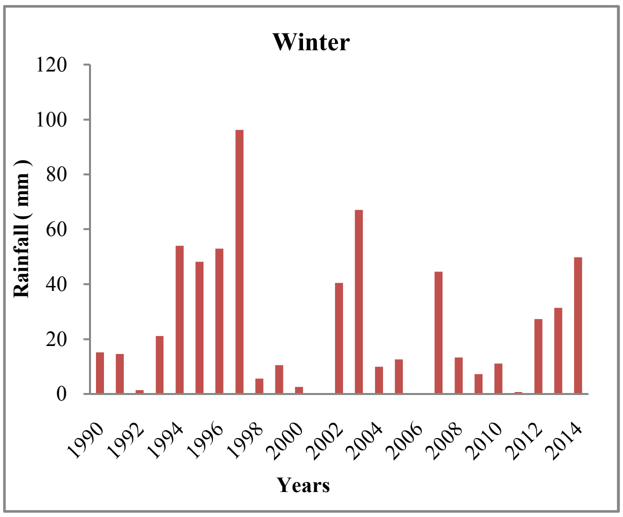

Fig 7(b) Seasonal rainfall series (winter season) for the period of 1990-2014

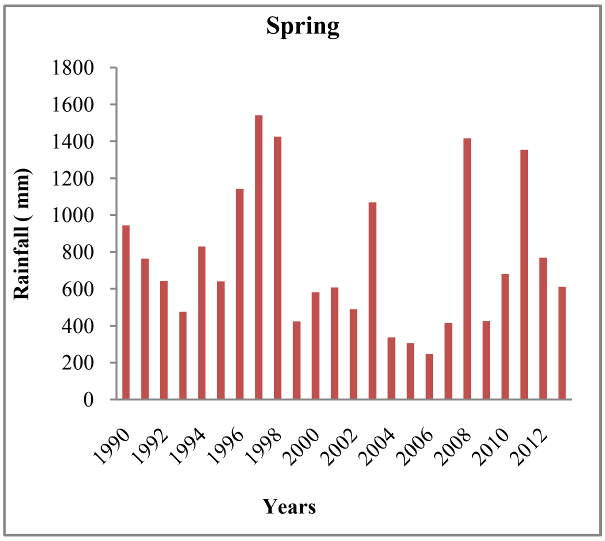

Fig 7(c) Seasonal rainfall series (spring season) for the period of 1990-2014

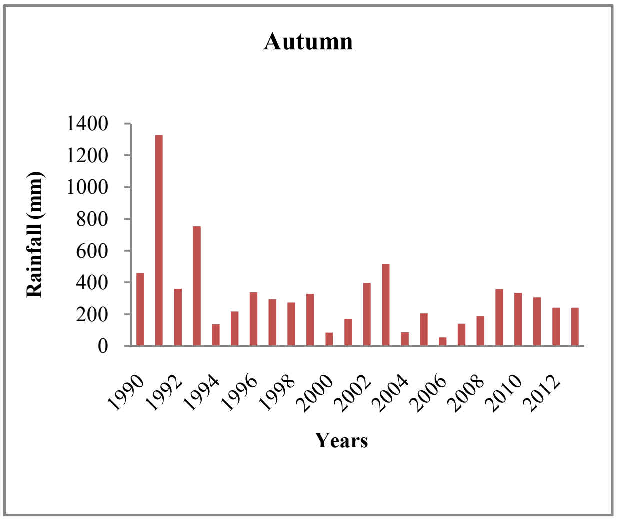

Fig 7 (d) Seasonal rainfall series (autumn season) for the period of 1990-2014

Trend analysis for rainfall in Chitrakoot region (Regression technique, Mann-Kendall and Sen's Slope)

Trend analysis of Chitrakoot region for the period of 1990 to 2014 has been done in the present study with of precipitation data. A regression technique, Mann-Kendall and Sen's Slope Estimator has been used for the determination of the trend. A trend is a significant change over time exhibited by a random variable, detectable by statistical parametric and non-parametric procedures. Onoz and Bayazit (2003) showed that the parametric t -test has less power than the non-parametric Mann–Kendall test when the probability distribution is skewed. The precipitation time series are aggregated in the annual time series and also in trimesters (spring, summer, autumn and winter) to further observe potential changes at the seasonal scale.

The result of trend analysis for monthly rainfall under Chitrakoot region are presented in Table-2 which shows the value of regression coefficient for annual and monthly rainfall along with its test of significance and R^2 value. R^2 values range from 0 to 1 and are commonly stated as percentages from 0 to 100%. Linear regression calculates an equation that minimizes the distance between the fitted line and all of the data points.

Table 1 Statistical summary of monthly rainfall

Time	Mean (mm)	Min (mm)	Max (mm)	SD (mm)	Skewness	Kurtosis	CV (%)
January	6.89	0.00	34.90	10.35	1.54	1.23	150.22
February	12.94	0.00	46.70	15.00	0.91	-0.61	115.92
March	5.17	0.00	49.47	12.61	2.97	8.18	243.91
April	3.30	0.00	58.99	11.87	4.68	22.56	359.70
May	2.27	0.00	18.16	4.60	2.98	8.33	201.75
June	116.90	7.86	694.61	151.53	2.68	8.53	129.62
July	313.66	41.60	818.77	185.00	0.86	0.78	58.98
August	330.3	90.48	702.83	174.95	0.57	-0.40	52.96
September	288.35	51.83	1323.00	271.20	2.76	9.17	94.05
October	33.46	0.00	144.47	44.14	1.27	0.41	131.92
November	3.80	0.00	32.47	8.69	2.73	6.88	228.68
December	6.19	0.00	90.84	18.56	4.49	21.03	299.84
Annual	1096.57	343.52	2111.70	494.81	0.47	-0.83	45.12

Table 2 Regression results for annual and monthly rainfall

SN	Month	P-value	t-Stat	R^2	Lower 95%	Upper 95%
1	Jan	0.904	0.120	0.0005	-1129.41	1269.69
2	Feb	0.657	-0.449	0.0093	-2132.51	1370.77
3	Mar	0.798	0.258	0.0027	-1293.11	1661.72
4	Apr	0.128	1.577	0.0970	-313.858	2331.93
5	May	0.629	0.488	0.0099	-410.539	664.470
6	Jun	0.443	-0.780	0.0267	-24159.1	10921.60
7	Jul	0.961	-0.049	0.0002	-22222.6	21185.55
8	Aug	0.089	1.776	0.1213	-2940.52	38108.09
9	Sep	0.021	2.466	0.21395	5702.919	65886.98
10	Oct	0.301	-1.057	0.0495	-8133.64	2638.94
11	Nov	0.858	-0.179	0.0015	-1181.61	993.012
12	Dec	0.413	0.832	0.0301	-1368.62	3206.04
13	Annual	0.058	1.987	0.1412	-2111.86	105489.80

In general, a model fits the data well if the differences between the observed values and the model's predicted values are small. R^2 is a statistical measure of how close the data are to the fitted regression line. The higher the R^2, the better the model fits your data.

Regression factors for estimating rainfall different months under Chitrakoot region from Table-2 showed that highest R^2 was obtained for September month (21.39 %) followed by August (12.13 %) while lowest R^2 (0.02 %) was obtained for July month. Rainfall pattern of months do not present statistically significant at 95 % confidence level.

In the non parametric Mann-Kendall test, trend of rainfall for 25 years from January to December has been calculated for each month individually together with the Sen's magnitude of slope. In the Mann-Kendall test describes the trend of the series for individual 12 months From January to December which are -0.268, 0.027, -0.065, -0.121,-0.211, -0.007, 0.073, -0.225, -0.268, 0.040, 0.004, and -0.036 respectively. For February, July, October and November there is an evidence of rising trend while test value is showing negative trend in January, March, April, May, June, August, September, and December. Thus test values for four months show a positive trend and for other eight months it shows negative trend representing almost non-significant condition (Table-3).

The estimated Sen's slope has been calculated for January to December showing rising slope magnitude February (0.008), July (2.564), and October (0.068), although non-significant. Only the month January (-7.255), March (-0.006), April (-0.006), May (-0.029), June (-0.116), August (-7.277) and September (-0.255) shows non-significant decreasing trend but the months of November (0.00) and December (0.00) show no change in the Sen's Slope while others are depicting either increasing or decreasing trend (Table-3).

This result is quite significant as the months where Mann-Kendall trend analysis has shown negative trend, similar negative slope has been observed for the Sen's Slope and vice versa.

Table 3 Mann-Kendal result for annual and monthly rainfall

SN	Month	Mann Kendall	P- value	Sen's Slope
1	January	-0.268	0.070	-7.255
2	February	0.027	0.870	0.008
3	March	-0.065	0.672	-0.006
4	April	-0.121	0.413	-0.006
5	May	-0.211	0.147	-0.029
6	June	-0.007	0982	-0.116
7	July	0.073	0.628	2.564
8	August	-0.225	0.132	-7.277
9	September	-0.268	0.070	-7.255
10	October	0.04	0.804	0.068
11	November	0.004	1.000	0
12	December	-0.036	0.836	0
13	Annual	-0.53	0.108	-0.13

Correlation coefficient between Mann Kendal and Sens Slope method (r) = 0.83
R – squared = 0.69, Test the significance (t value) = 4.30

The Correlation between Mann-Kendall trend analysis and Sen's Slope in respect of monthly rainfall was observed for different sets of months. The result of correlation coefficient (0.83) between Mann-Kendall trend analysis and Sen's Slope was found significant at 0.01 probability level. To test the significance of the correlation coefficient't' test (4.30) was used. The best way to interpret the value of correlation '*r*' is to square it to calculate r^2 called coefficient of determination, but scientists calls it "R- squared". It is a value that ranges from zero to one, and is the fraction of the variance in the two variables that is "shared". The r^2 of Mann-Kendall trend analysis and Sen's Slope was obtained 0.69 mean 69 % of the variance in Mann-Kendall trend analysis can be explained by variation in Sen's Slope. More simply, 69 % of the variance is shared between Mann-Kendall trend analysis and Sen's Slope.

The correlation coefficient between Mann-Kendall trend analysis and Sen's Slope with its test of significance (t-test statistic) and r^2 value are presented in Table-3.

In the study area the increase in annual rainfall observed during fifteen year is caused by increase in spring, autumn and winter rainfall total. However is considerable amount of rainfall decrease for autumn which is statistically significant at 95% confidence limit during study period, which in the case in about 0.01^0C is year during the period 1990-2014. This finding is not similar to global warming rate which is estimated 0.6 ^{0}C for the past century. However the rate of change (during the period 1990-2014) is around 0.36.

Fig.-3 showed that the cumulative deviations of rainfall pattern in the study area for the periods of (1990-2014). Result reveals that a cyclic pattern of variations with alternating drier and wetter years is suggested. An increase of annual rainfall up to the early 1994-1995 followed by decrease until 1990 the last four year showed slight rainfall decrease. Dry periods can be determined in 2002 to 2006 wetter periods on the other hand; can be identified in 1994-1998 (above 2000mm, 1998-2002 below 2000mm and about 1900mm).

Temperature

Annual and Monthly Temperature Analysis

A temperature trend has crucial impacts on the other water cycle in the study area.

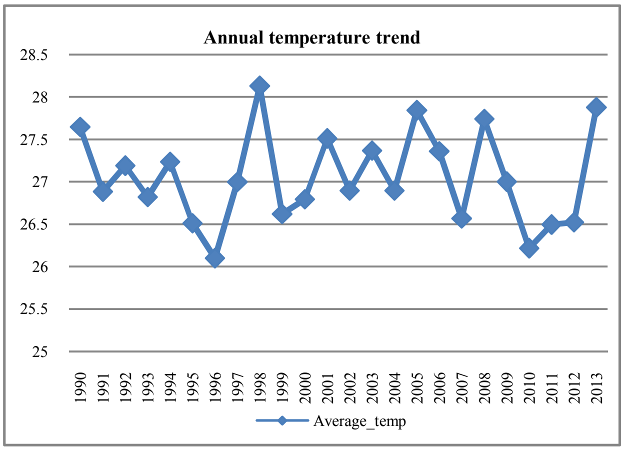

Fig 8 Mean annual temperature trend in the period 1990-2014

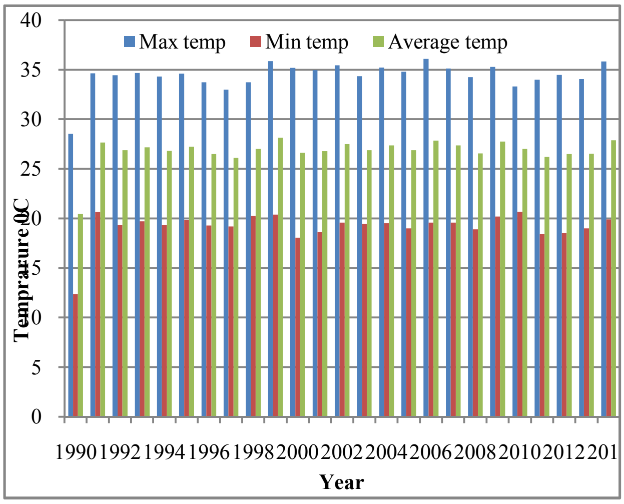

Fig 9 Maximum and minimum annual temperature trends in the period 1990-2014

So that analysis of trends in annual seasonal and monthly temperature data conducted for the periods of record 1990-2014. Fig.-8 represents the mean annual temperature and its trend in the period under examination.

Using a linear regression model, the rate of change is defined by the slope of regression significant for 15 years. Trends in monthly temperature data are consistently positive most of the months excluding month of December and statistically significant in February, March, April and September at 95% confidence level during the periods of 1990-2014. Yearly mean maximum, minimum and average temperature data were depicted in fig.-9 and monthly sum maximum and minimum temperature data were depicted in fig.-10.

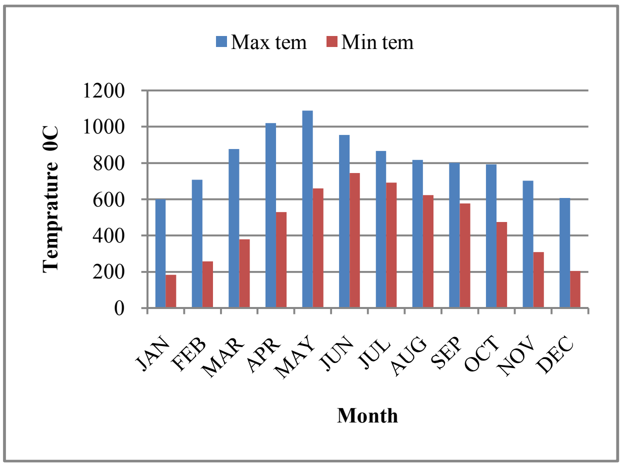

Fig 10 Annual temperature trends in the period 1990-2014

Fig.-8 shows cumulative deviation of temperature pattern in the study area for the period of 1990-2014. Result reveals that a cyclic pattern of variation with alternately warming and cooling year is suggested. The last 2 year where characterized increase of temperature up to 2014 and was followed by increase with 1996-2006 (cooling period can be determined 1996-2008).

Trend analysis for temperature in Chitrakoot region (Regression technique, Mann-Kendall and Sen's Slope)

Statistical summary of monthly maximum, minimum and average temperature were given in Table-4 to 6. Man Mann-Kendall test and linear regression analysis results were given in Table- 7 to 8. Trend analysis of temperature data on annual, monthly and seasonally in Chitrakoot region for the period of 1990 to 2014 has been. Mann-Kendall and Sen's Slope Estimator has been used for the determination of the trend.

The result of trend analysis for monthly temperature under Chitrakoot region are presented in Table-7 which shows the value of regression coefficient for annual and monthly rainfall along with its test of significance and R^2 value.

Regression factors for estimating temperature different months under Chitrakoot region from Table-7 showed that highest R^2 was obtained for September month (19.03 %) followed by December (17.84 %) while lowest R^2 was obtained for January month. None of the month showed statistically significant at 95 % confidence level for monthly Temperature.

The results of Mann-Kendall test; trend of temperature for 25 years from January to December has been calculated for each month individually together with the Sen's magnitude of slope.

In the Mann-Kendall test describes the trend of the temperature for individual 12 months from January to December which are -0.120, 0.113, 0.173, 0.127, -0.060, -0.073, -0.193, 0.107, 0.247, -0.247, -0.033, and 0.147 respectively. For February, March, April, July, August, September and December there is an evidence of rising trend while test value is showing negative trend in January, May, June, October and November. Thus test values for seven months show a positive trend and for other five months it shows negative trend representing almost non-significant condition (Table-7). The result of annual trend of temperature are reported negative trends but result is not statistically significant at 95 % confidence limit (MK= -0.053) during the period 1990- 2014.

The result of Sen's slope has been calculated for January to December showing rising slope magnitude February (0.021), March (0.046), April (0.021), August (0.026), September (0.054) and December (0.029), although non-significant. Only the month January (-0.021), May (-0.013), June (-0.033), July (-0.05), October (-0.057) and November (-0.009) shows non-significant decreasing trend. This result is quite significant as the months where Mann-Kendall trend analysis has shown negative trend, similar negative slope has been observed for the Sen's Slope and vice versa.

The Correlation between Mann-Kendall trend analysis and Sen's Slope in respect of monthly temperature was observed for different sets of months. The result of correlation coefficient (0.98) of temperature between Mann-Kendall trend analysis and Sen's Slope trend was found significant at 0.01 probability level. To test the significance of the correlation coefficient't' test (18.30) was used. The r^2 of Mann-Kendall trend analysis and Sen's Slope was obtained 0.97 mean 97 % of the variance in Mann-Kendall trend analysis can be explained by variation in Sen's Slope trend analysis. More simply, 97 % of the variance is shared between Mann-Kendall trend analysis and Sen's Slope trend analysis. The correlation coefficient between Mann-Kendall trend analysis and Sen's Slope with its test of significance (t-test statistic) and r^2 value are presented in Table-7.

Table 4 Statistical summary of monthly maximum temperature

Time	Mean (^{0}C)	Min (^{0}C)	Max (^{0}C)	SD (^{0}C)	Skewness	Kurtosis	CV (%)
January	24.99	22.31	28.36	1.78	0.36	-0.78	7.12
February	29.35	25.87	34.79	1.84	0.87	2.56	6.27
March	36.45	32.53	39.41	1.77	-0.49	-0.28	4.86
April	42.47	39.56	45.54	1.25	0.31	0.83	2.94
May	45.34	43.45	47.5	0.97	0.07	0.1	2.14
June	41.62	19.79	45.54	5.08	-3.56	15.03	12.21
July	36.09	26.48	41.44	2.84	-1.3	4.78	7.87
August	34.06	26.47	37.98	2.11	-1.86	6.95	6.19
September	33.4	25.49	37.28	2.25	-1.69	6.17	6.74
October	33.04	20.56	36.51	2.98	-3.32	14.04	9.02
November	29.27	14.03	32.4	3.43	-4.09	18.71	11.72
December	25.29	10.33	29.12	3.52	-3.64	15.29	13.92

Table 5 Statistical summary of monthly minimum temperature

Time	Mean (^{0}C)	Min (^{0}C)	Max (^{0}C)	SD (^{0}C)	Skewness	Kurtosis	CV (%)
January	7.62	3.48	10.87	1.9	-0.26	-0.5	24.93
February	7.62	3.48	10.87	1.9	-0.26	-0.5	24.93
March	15.16	11.84	17.85	1.53	-0.27	-0.19	10.09
April	21.21	19.04	24.31	1.31	0.62	0.3	6.18
May	26.37	23.53	28.56	1.28	-0.55	-0.25	4.85
June	29.78	28.34	31.16	0.86	-0.16	-1.19	2.89
July	27.68	15.34	30.78	2.77	-3.88	17.79	10.01
August	25.93	11.3	27.5	3.15	-4.72	22.78	12.15
September	24.04	2.34	25.9	4.65	-4.8	23.32	19.34
October	19.74	0.72	34.02	5.07	-1.44	11.34	25.68
November	13.43	12.01	17.26	1.42	1.33	1.29	10.57
December	8.53	5.32	12.21	1.63	-0.04	0.34	19.11

Table 6 Statistical summary of monthly average temperature

Time	Mean (^{0}C)	Min (^{0}C)	Max (^{0}C)	SD (^{0}C)	Skewness	Kurtosis	CV (%)
January	16.31	14.66	19.16	1.23	0.98	0.62	7.54
February	19.83	17.24	23.02	1.26	-0.06	1.02	6.35
March	25.81	23.82	28.46	1.14	0.3	0.03	4.42
April	31.84	29.32	34.93	1.13	0.54	1.52	3.55
May	35.85	34.21	37.48	0.84	-0.2	-0.7	2.34
June	35.7	25.08	38.14	2.64	-2.92	10.93	7.39
July	31.89	20.91	36.11	2.74	-2.62	10.81	8.59
August	29.99	18.88	32.74	2.52	-3.95	17.91	8.40
September	28.72	13.92	31.03	3.26	-4.37	20.52	11.35
October	26.39	10.64	34.02	3.75	-3.1	15.16	14.21
November	21.07	7.01	23.44	3.06	-4.54	21.64	14.52
December	16.91	7.82	18.85	2.09	-3.83	17.01	12.36

Table 7 Mann-Kendall results for annual and monthly temperature

SN	Month	Mann Kendall	P-value	Sens Slope
1	Jan	-0.120	0.418	-0.021
2	Feb	0.113	0.446	0.021
3	Mar	0.173	0.237	0.046
4	Apr	0.127	0.392	0.021
5	May	-0.060	0.695	-0.013
6	Jun	-0.073	0.628	-0.033
7	Jul	-0.193	0.186	-0.050
8	Aug	0.107	0.474	0.026
9	Sep	0.247	0.089	0.054
10	Oct	-0.247	0.089	-0.057
11	Nov	-0.033	0.836	-0.009
12	Dec	0.147	0.320	0.029
13	Annual	-0.053	0.729	-0.130

Correlation coefficient between Mann Kendal and Sens Slope method (r) = 0.98
R –squared = 0.97, Test the significance (t value) = 18.30

Table 8 Regression statistic results for annual and monthly temperature

SN	Month	P-value	t-Stat	R^2	Lower 95%	Upper 95%
1	Jan	0.929	0.089	4.22×10^{-6}	-390.14	425.34
2	Feb	0.688	-0.406	0.020	-175.44	117.86
3	Mar	0.348	-0.957	0.075	-188.22	69.13
4	Apr	0.499	-0.686	0.058	-171.81	86.23
5	May	0.292	1.078	0.0045	-47.078	149.55
6	Jun	0.155	1.467	0.060	-87.196	512.79
7	Jul	0.879	-0.153	0.005	-344.61	296.91
8	Aug	0.144	-1.512	0.118	-512.45	80.23
9	Sep	0.046	-2.112	0.190	-741.91	-6.84
10	Oct	0.608	-0.519	0.018	-581.04	348.21
11	Nov	0.135	-1.549	0.112	-630.98	91.31
12	Dec	0.053	-2.03788	0.178	-469.21	4.10
13	Annual	0.434	0.795401	0.015	-2145.96	4827.10

CONCLUSION

In this study rainfall and temperature data from 1990-2014 where used to identify seasonally, variability, trends in Chitrakoot. From analysis of annual seasonal and monthly rainfalls data series it can be concluded that rainfall characteristics of the area is changing even though results of trend analysis of annual rainfall data show no statistically significant trend for period of record considered.

The annual and seasonal trends of precipitation were investigated by the Mann–Kendall test, the Sen's slope estimator and the linear regression in this study. For this purpose, rainfall and temperature data over the Chitrakoot region for the period of 1990– 2014 were analyzed. A brief summary of the findings of the study is presented below.

1. The results of the Mann- Kendall trend analyses showed that monthly rainfall and temperature an overall upward and downward trend over the Chitrakoot region.
2. The annual rainfall showed that non-significant decreasing trend at the 95% and 99% confidence levels in the rainfall and temperature over the Chitrakoot region.
3. The results of the Sen's slope trend analyses also showed that that monthly rainfall and temperature an overall upward and downward trend and the annual rainfall and temperature showed that non-significant decreasing trend at the 95% and 99% confidence levels over the Chitrakoot region.
4. The results of the monthly and annual rainfall estimated by linear regression techniques obtained poor fitted trend with low r^2 value for both rainfall and temperature parameter over the Chitrakoot region.
5. The rainfall behavior especially the variability and trend is important for the proper design of water related system such as drainage system and clean water supply in rapidly growing cities like Chitrakoot City. From the result of the linear regression and Mann- Kendall analysis, there is insignificant increasing trend in annual mean rainfall data.
6. All the results signify no significant detectable effect of global warming on the annual, monthly and seasonal rainfall trend in Chitrakoot Region. Air pollution and deforestations from urbanization process are some of the factors that affecting the climate change. As the environmental impact from urbanization process maybe quite minimal on this area, this could lead to the least change in rainfall trend.

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