ASSESSMENT OF TRENDS FOR HYDRO-METEOROLOGICAL VARIABLES FOR BANDA DISTRICT OF BUNDELKHAND REGION, INDIA

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Abstract

Climate variability, particularly, that of the annual air temperature and precipitation, has received a great deal of attention worldwide. The magnitude of the variability of the factors changes according to the locations. In the view of changing climate, increased water scarcity and frequent occurrence of extreme hydrologic events, it is very important to analyze long-term pattern of hydro-meteorological trends. The present study aims to determine trends in annual and seasonal patterns of precipitation, air temperature, and reference evapotranspiration for the period 1901-2002 in the Banda district of Bundelkhand region. In this study, linear trend analysis and Mann-Kendall non-parametric tests were employed for detection of trends and the magnitudes of the trends were determined using Sen's Slope estimator test. The results of the study shows that there is a significant rise in temperature and falling trends have been observed in the rainfall and groundwater level over the years.

Keywords: Climate change, Evapotranspiration, Groundwater levels, Trend Analysis, Mann-Kendall Test, Sens's Slope Estimator

1. Introduction

Agriculture in Bundelkhand is rainfed, diverse, complex, under-invested, risky and vulnerable. In addition, extreme weather conditions, like droughts, short-term rain and flooding in fields add to the uncertainties and seasonal migrations. The scarcity of water in the semi-arid region, with poor soil and low productivity further aggravates the problem of food security. Ironically, this once rich region has now become one of the poorest parts of the country. Except for Sagar and Jhansi districts, around 60 % of main workers in Bundelkhand are engaged in agriculture as cultivators or labourers, showing a higher reliance on agricultural land compared to other parts of rural India. Industrialization has been sporadic and this in turn has led to low levels of urbanization. Living conditions are harsh especially for the rural poor who depend mainly on agricultural incomes for sustenance, and are therefore highly vulnerable to drought and failure in cropping systems and loss of employment and incomes. According to Tendulkar Committee Report 2009 estimates of poverty line and HDR 2004-05 with recurring drought and failure in agriculture, the level of poverty in rural areas has increased since a large number of farmers depend on rain fed agriculture (Planning Commission, 2009 & CSO, 2010). According to the inter-ministerial central team report (Samra, 2008), even though about 45 % of net sown area in Bundelkhand is irrigated, the water supply is not adequate.

Banda district largely consists of irregular uplands with outcrops of rocks intermingling with mostly lowlands, frequently under water during rainy season. The Baghein river traverse the district from south-west to north-east. The tract lying to the right of the river is intersected by numerous smaller river and rivulets (Nallas), but to its left is a flat expanse, for the most part made up of Mar and Kabar soils, eroded and converted into ravines along the banks of the Ken and the Yamuna and to a lesser extent, the Baghein river and the Gadara Nala. The general slope of the district is from southwest to north-east, along with the course of Baghein river as mentioned earlier. The district falls into two sharly defined portions; one is upland called Patha, situated on the Vindhyan plateau in the south of Mau and Karwi tehsils(presently known as Chitrakoot district), the other is lowlands of alluvium (presently known as Banda district).

The variability and trends in hydro-meteorological variables has received a wide spread attention among meteorologists and hydrologists across the globe during past several years because of its relevance to climate change. Capturing typical properties of time series, like trends, is highly relevant for the discussion of potential impacts of global warming or flood / drought occurrences.

Although, the assessment of trends in climatology and hydrology is a matter of debate due to changing variability and non- fixedness of the variables. These variability in conjunction with climatic change causing significant impacts to agriculture, ecology and infrastructure. The Indian Summer Monsoon (Southwest Monsoon) occurs from June to September and contributes approximately 80% to the total annual precipitation in India. The majority of the Indian agriculture is dependent on it, which is critical for the availability of freshwater for drinking and irrigation. Changes in climatic variable over the Indian region, particularly the SW monsoon, would have a significant impact on agricultural production, water resources management and overall economy of the country.

2. Background and status of the study

Precipitation, air temperature and evapotranspiration are important components of hydrological cycle and contribute vital role in agriculture, water availability and planning of irrigation system development and management (Khare et al., 2006; Himanshu et al., 2017a, 2017b; Pandey et al., 2016). Trend analysis of rainfall and evapotranspiration was carried out by scientist community from different countries using different methods (Adarsh and Janga Reddy, 2015; Bandyopadhyay et al., 2009; Bawden et al., 2014; Himanshu et al., 2017a, 2017b; Jain et al., 2013; Jiang et al., 2002; Mishra et al., 2009; Partal and Kahya, 2006; Pingale et al., 2014; Shifteh Some'e et al., 2012; Widmann and Schär, 1997); Pandey et al. (2017) examined the trend of annual, seasonal and monthly precipitation applying discrete wavelet transform (DWT) and Mann Kendall test over seven Indian regions. Results indicate both, positive and negative trend for the different regions. Adarsh and Janga Reddy (2015) investigated the rainfall trend for southern India using non-parametric methods and wavelet transforms. Sequential Mann Kendall test was applied to analyze the sequential changes in annual and seasonal trend. Kumar et al.(2016) investigated the trend of annual and seasonal precipitation and temperature over Jharkhand (India) applying non parametric tests. Results imply no significant trend in monsoon and summer session for maximum and minimum temperature while significant decreasing trend of 2.04 mm/year observed during the monsoon season for precipitation. Suryavanshi et al. (2014) examined the trend in temperature and potential evapotranspiration over Betwa basin, India. Sonali and Kumar (2013) analyzed trend of maximum and minimum temperature of annual, monthly, winter, pre-monsoon, monsoon and post-monsoon. The studies were carried out for three time slots 1901–2003, 1948–2003 and 1970–2003, for India as a whole and seven homogeneous regions of India. Authors consider the effect of serial correlation, trend detection analysis while applying MK test, Sen's slope estimator and other non-parametric methods. Mishra et al. (2009) analyzed the impact of climate change on precipitation of Kansabati basin, India. Trend and persistence of projected precipitation for annual, monsoon and pre-monsoon periods were investigated. Results implied that there will be likely an increasing trend based on A2 scenario and decreasing trend based on B2 scenario for both annual and monsoon periods during 2051–2100.

3.Materials & Methods

3.1 Study Area

Banda is the eastern most district of Bundelkhand. The district lies on the southern fringe of Uttar Pradesh at 25°47′96″N latitudes & 80°33′80″E longitudes. Yamuna is joined by Ken at Chillaghat, Bagein near Bilas, and Paisuni near Kankota villages. The hills of the district consist of the part of the Vindhyan plateau, also Banda forms part of the northern fringe of the peninsular India coming in contact with the Gangetic alluvium. The total area of district is 4,347.72 sq. km. supporting a population of 17,99,410 with a density of 350 persons per sq. km. It has 8 blocks with 694 villages. Net sown area is 3.51 lakh ha and cropping intensity of the district is 112.2%. The annual rainfall is 850 mm. Around 1.23 lakh ha area is under cultivation.

Climatology of the region is semi-arid with hot and dry summer (from March to June) and cool winter (from November to February).In summer,temperature rises upto 45°C or even more while winter temperature varies between 4 °C to 18 °C .Monsoon season is very important for agriculture because of maximum rainfall.

3.2 Data Collection

To study the temporal changes in climate of the Banda district, a trend analysis of the climatic variables were considered. Precipitation, average monthly temperature and reference evapotranspiration data of 102 years length (1901–2002) were used in this study, and series downloaded from India water portal website (http://www. indiawaterportal.org/metdata) maintained by Indian Meteorological Department (IMD). Seasonal and annual analysis was done for 3 stations of precipitation, average monthly temperature and reference evapotranspiration (Fig. 1). In general, spring or pre-monsoon season starts from March to May, monsoon season from

June to August, autumn or post monsoon in September to November, and winter from December to February.

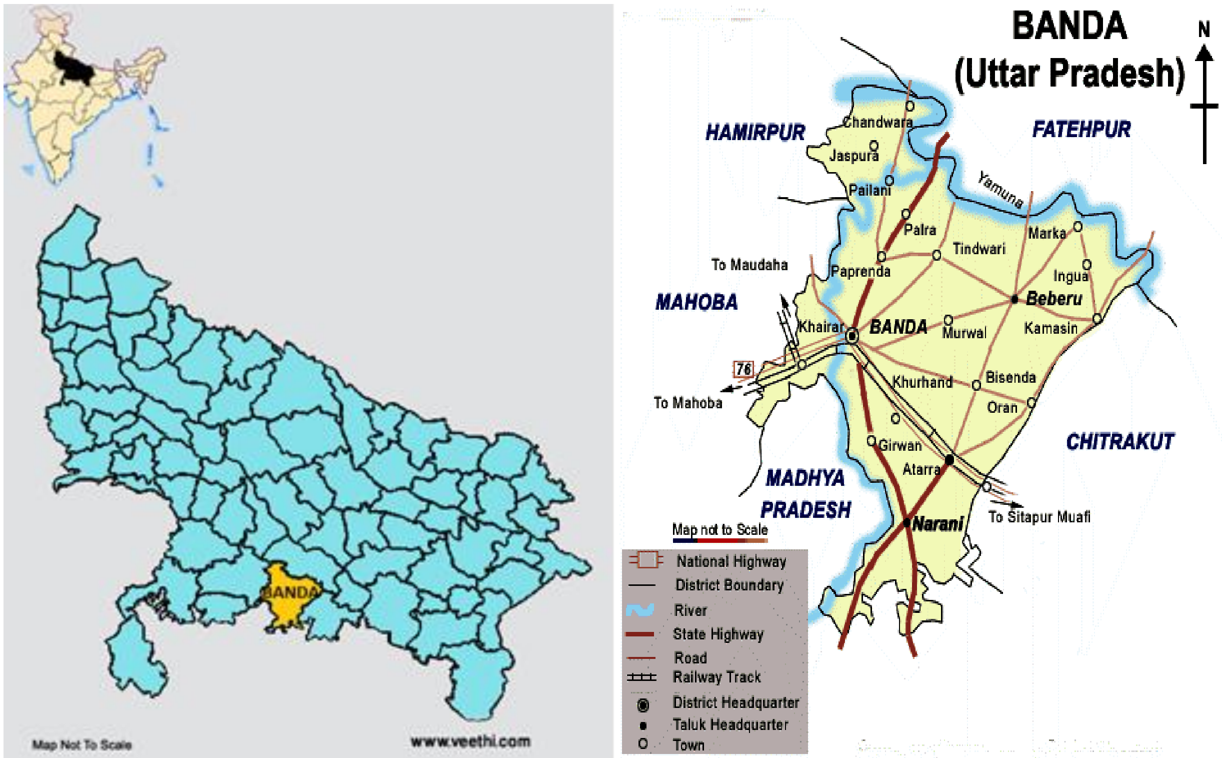


Fig.1 Location map of the study area

3.3 Purpose of Trend Testing

A series of observations of a random variable (rainfall, temperature, ETo, etc.) have been collected over some period of time. We would like to determine if their values are generally increasing or decreasing (getting "better" or "worse"). In statistical terms this is a determination of whether the probability distribution from which they arise or its proposition have changed over time. The null hypothesis: Ho is that there is no trend. However, any given test brings with it a precise mathematical definition of what is meant by "no trend", including a set of background assumptions usually related to type of distribution and serial correlation. The outcome of the test is a "decision" either Ho is rejected or not rejected. Failing to reject Ho does not mean that it was "proven" that there is no trend. Rather, it is a statement that the evidence available is not sufficient to conclude that there is a trend.

The inherent variability of any natural time series must be considered whenever attempting to detect trends in a natural time series. There is always difficulty associated with differentiating between natural variability and trends. This argues for the development of a rigorous procedure for detecting trends.

Hydrologic and climatic variables are important indicators of climatic change. Precise selection of variables is needed for any trend study as these variables tend to reflect climatic change and can help in understanding the relationships between hydrology and climate. Numerous studies have suggested different variables for detecting climatic change. This report contains the detailed analysis of trend and its magnitude detection of rainfall, temperature and evapotranspiration

3.4 Trend Detection Test

The time series of temperature and ground water level data were analyzed using the Mann- Kendall non-parametric test for trend. Mann (1945) originally used this test and Kendall (1975) subsequently derived the test statistic distribution. This test was found to be an excellent tool to ascertain presence of statistically significant trend in hydrological climatic variables, such as temperature, precipitation and streamflow, with reference to climate change and wildly used by the other researchers in similar applications (Kumar et.al. 2005, Bhutiyani, 2008, Singh et al., 2008a, Kumar & Jain 2010). Pre-whitening is the most commonly used procedure to eliminate the effect of serial correlation and autocorrelation in any trend analysis, but due to the very large sample size (n >50) and the slope of trend was high (>0.01) pre-whitening of the data series was not carried out as suggested by Bayazit & Onoz (2007). However all the data was standardized before any kind of analysis. Prior to perform the testing the monthly time series of temperature were aggregated into seasonal and annual time series and standardized in order to bring uniformity and facilitate comparison between the hydrological responses of these districts. The rainfall, temperature and ETo data of the four seasons namely, pre-monsoon or spring season (March – May), southwest monsoon season (June – September), post monsoon (October - November) & northeast monsoon season or winter season (from December of the current year to February of the next year) and annual average of these variable were used to study the trends and temporal fluctuations in climate over the Banda and adjacent districts.

3.5 Methodology

3.5.1. *Mann-Kendall test*

Mann-Kendall is the non-parametric test for detecting a trend in hydro-climatic time series. It is hypothesis testing to check the existence of trend in the terms of yes or no (Kundu et al., 2015; Kundu et al., 2014; Meena et al., 2015). It is simple and strong method, in addition to this, it can also handle the missing values and outliers (Yue et al., 2002). The Kendall's test searches for a trend in a time series without specifying whether the trend is linear or nonlinear.

The trend test is applied to a time series x_k ranked from k = 1,2……….n-1, and x_j ranked from j = k+1,2,……….n. Each data point x_k is used as a reference point and is compared with all other data points x_j .The Kendall statistics ‘S’ is estimated as

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \mathrm{sgn}\left(x_j - x_k\right) \qquad Sgn\left(x_j - x_k\right) = \begin{cases} +1 & if\ \left(x_j - x_k\right) > 0 \\ 0 & if\ \left(x_j - x_k\right) = 0 \\ -1 & if\ \left(x_j - x_k\right) < 0 \end{cases}$$

The variance of the statistic ‘S’ is defined by

$$Var(S) = \left[n(n-1)(2n+5) - \sum_t t(t-1)(2t+5) \right] \Big/ 18$$

The notation t is the extent of any given tie and $\sum_t$ denotes the summation over all ties. In cases where the sample size n > 10, the standard normal variate z is computed by using Equation (5) (Douglas *et al*., 2000). In a two-sided test for trend, H_0 should thus be accepted if $|z| \leq z_{\alpha/2}$ at the α level of significance. A positive value of ‘S’ indicates an ‘upward trend’; likewise, a negative value of ‘S’ indicates ‘downward trend’.The test statistics Z_{mk} is estimated as

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

The Mann-Kendall test has two parameters that are of importance to trend detection. These parameters are the significance level that indicates the trends strength and the slope magnitude estimates that indicates the direction as well as the magnitude of the trend. The MK test checks the null hypothesis of no trend versus the alternative hypothesis of the existence of increasing or decreasing trend. If Z_{mk} is positive, then the trend is increasing, and if Z_{mk} is negative, then the trend is decreasing.

3.5.2. *Sen’s Slope Estimator Test*

The magnitude of the trend in a time series was determined using a non-parametric Sen's slope estimator method (Sen, 1968). This Method assumes a linear trend in the time series. In this method, the slope (T_i) of all pairs are first calculated by

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

Where X_j and X_k area data values at time j and k (j>k) respectively. The median of these N values of T_i is Sen's estimator of slope which is calculated as

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

A positive value of β indicates an upward (increasing) trends and a negative value indicates a downward (decreasing) trend in the time series.

4. Results and discussions

The results for the non-parametric Mann-Kendall (MK) test applied to ascertain the significance of trends of the Z- values of the Banda district along with adjacent districts namely Chitrakoot and Hamirpur of the Bundelkhand region for seasonal and annual time series for rainfall, monthly average temperature and reference evapotranspiration ETo are represented in the respective tables in the further sub-section. Seasonal trend analysis of the entire monthly rainfall, ETo and temperature data (1901-2002) based on the four prominent and distinct seasons viz. pre-monsoon or spring season (March – May), southwest monsoon season (June – September), post monsoon (October - November) & northeast monsoon season or winter season (from December of the current year to February of the next year) along with annual data series were also carried out for better interpretation and understanding of the trend.

4.1. Trend analysis

To study the temporal changes in climate of the Banda district, trend analysis of seasonal and annual average temperature, seasonal and annual rainfall, seasonal and annual reference evapotranspiration (ETo) climatic variables were considered along with two adjacent districts namely Chitrakoot and Hamirpur to detect the variations in the study area.

4.1.1 Rainfall

Simple Linear Regression trend has been performed for all the three districts and the results are shown in the Fig.2. From the figures it is evident that one cannot say whether there is ant trend exists in these districts. Inorder to find out the trend with significance level Mann-Kendall test has been applied on the same data.

Seasonal and yearly rainfall was analyzed for a period of 102 years (1901–2002). It can be seen that in Banda district the annual rainfall pattern shows a decreasing trend with non-significance. The pre- monsoon , post-monsoon & winter season shows a increasing trend although there is a decreasing trend in monsoon season. Annual Sen’s Slope estimator also shows 0.446mm decrease in rainfall magnitude. May & June monthly rainfall shows increasing trend with 95% & 90% significance respectively.

The results of the monthly rainfall series of the three districts are given in table 1 and annual & seasonal trend analysis results are given in table 2. From the results the Chitrakoot district the annual rainfall pattern shows a decreasing trend with non-significance. The pre-monsoon , post-monsoon & winter season shows a increasing trend although there is a decreasing trend in monsoon season. Annual Sen’s Slope estimator also shows 0.836 mm decrease in rainfall magnitude. Jan, May & June monthly rainfall shows increasing trend with 90% significance.

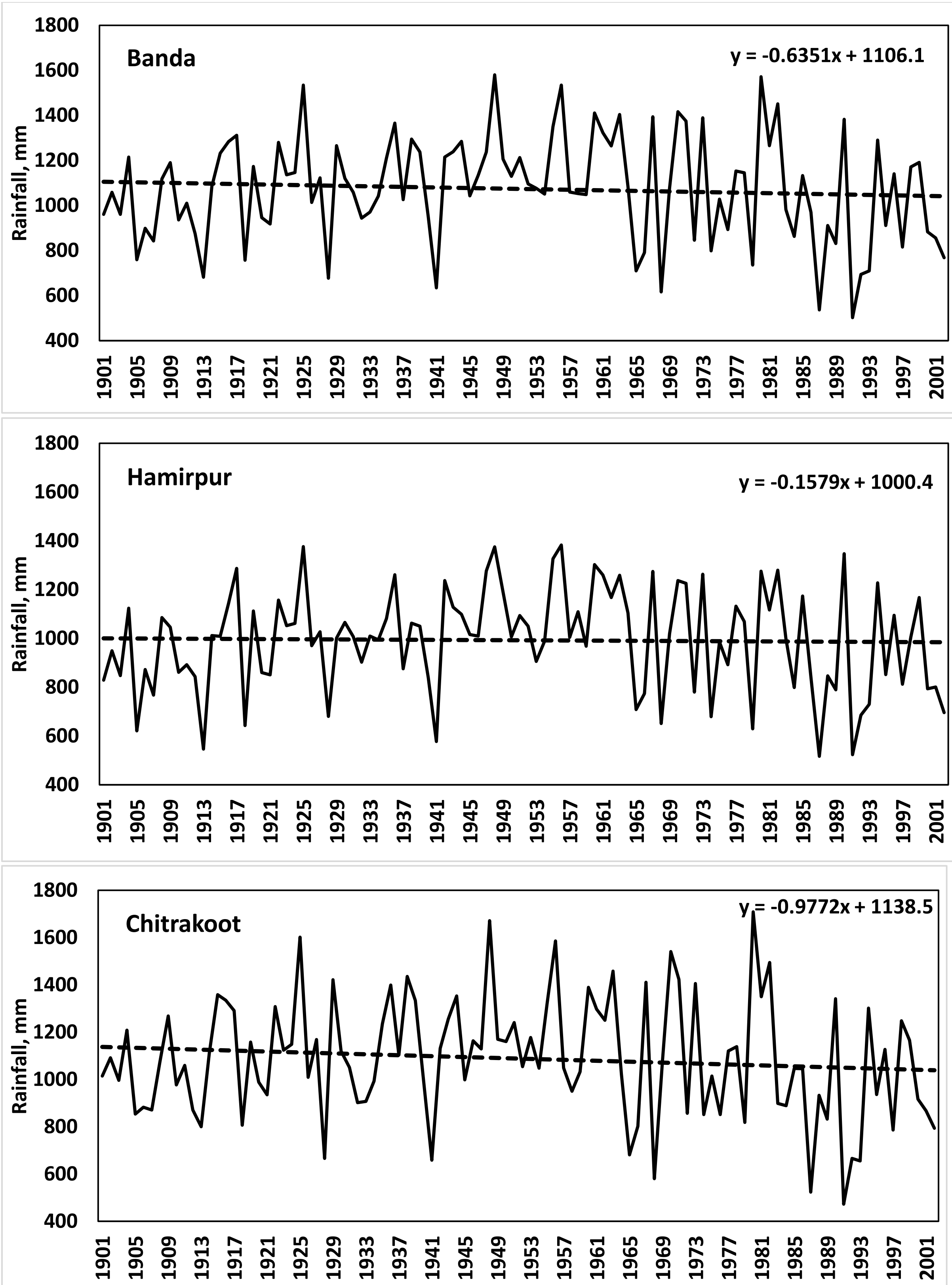


Fig. 2 Linear Trends of Annual Rainfall at different districts

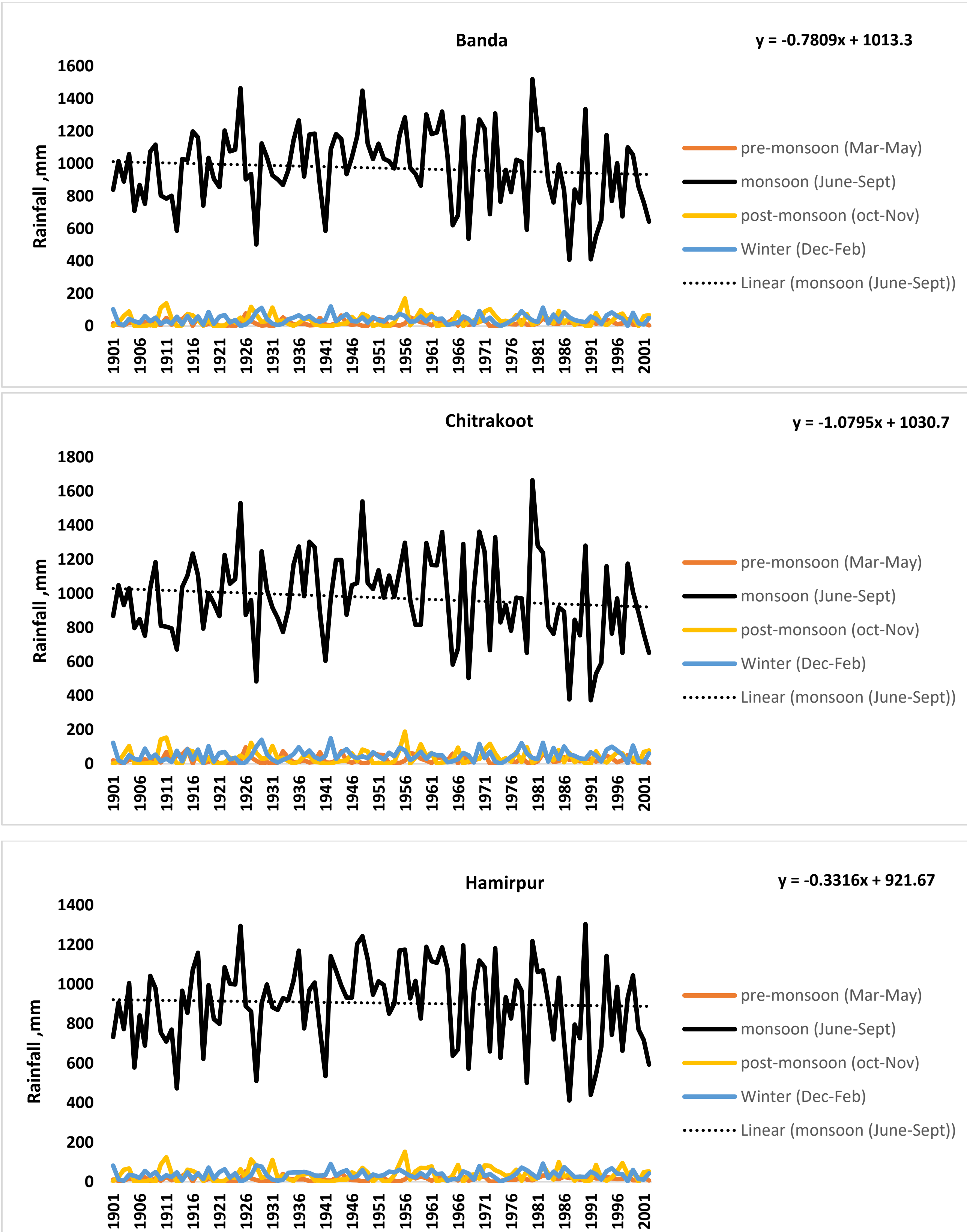


Fig. 3 Linear Trends of Season Rainfall at different districts

Also in Hamirpur district the annual rainfall pattern shows a increasing trend with non-significance. The pre-monsoon ,monsoon, post-monsoon & winter season shows increasing trend. Annual Sen's Slope estimator also shows 0.073mm increase in rainfall magnitude. May & pre-monsoon rainfall shows increasing trend with 95% & 90% significance respectively.

Table 1: Z-Value of MK Test for monthly series of rainfall for l02 years

SN1	District	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	Banda	1.39	-0.24	0.36	1.01	2.11*	1.65+	-1.48	-1.25	0.2	1.14	-0.25	0.46
2	Chitrakoot	1.82+	-0.42	-0.09	0.94	1.79+	1.77+	-1.58	-1.57	0.31	1.09	0.06	0.31
3	Hamirpur	0.8	-0.26	0.3	0.87	2.12*	1.5	-1.43	-0.43	0.17	1.34	-0.28	0.37
Significance Level: +90%; *95%; **99%; ***99.9%													

Table 2: Z-Value of MK Test for Annual and Seasonal series of rainfall for 102 years

S.No.	Districts	Annual	Pre-Monsoon	Monsoon	Post-Monsoon	Winter
1	Banda	-0.42	0.98	-0.49	1.44	0.80
2	Chitrakoot	-0.93	0.68	-1.07	1.27	0.83
3	Hamirpur	0.09	1.74+	0.12	1.58	0.34
Significance Level: +90%; *95%; **99%; ***99.9%						

4.1.2 Monthly Average temperature

Simple Linear Regression trend has been performed for all the three districts and the results are shown in the Fig.4. From the figures it is evident that one cannot say whether there is ant trend exists in these districts. Inorder to find out the trend with significance level Mann-Kendall test has been applied on the same data.

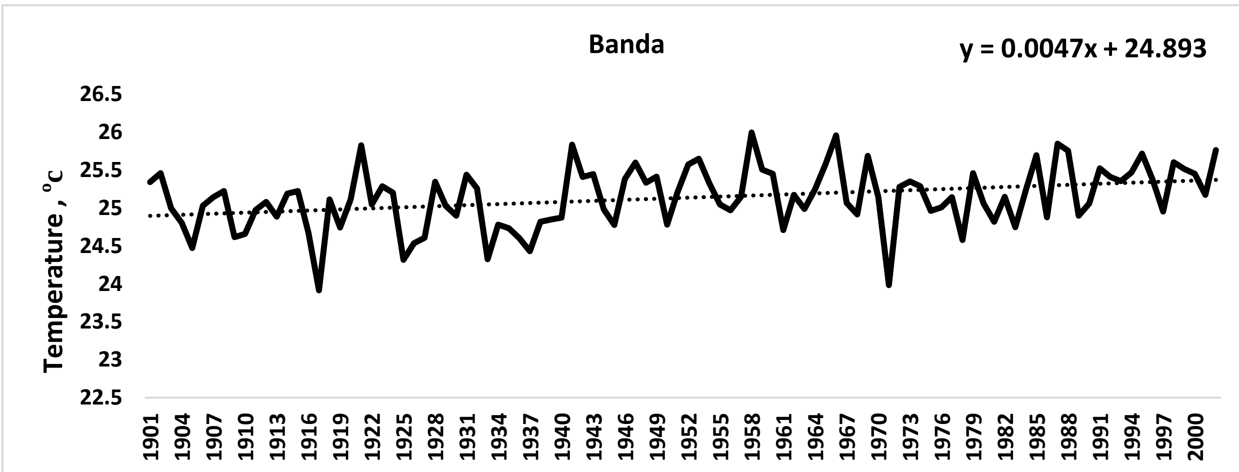
The Monthly Average temperature was analyzed for a period of 102 years (1901–2002). It can be seen from Table 3 that in Banda district the monthly annual average temperature pattern shows increasing trend with 99% significance. The post-monsoon & winter season shows increasing trend with 99% significance. Annual Sen's Slope estimator also shows 0.057℃ increase in temperature.

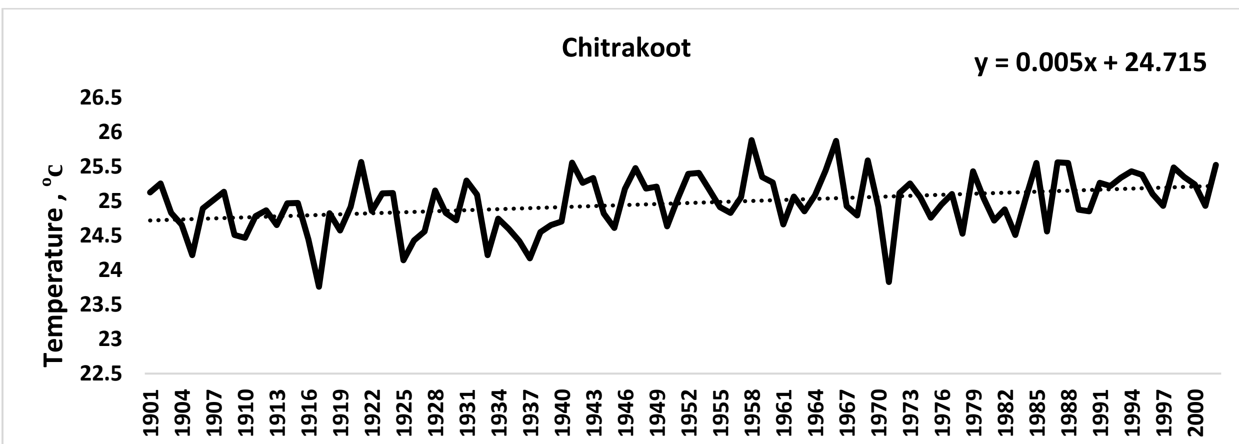
In Chitrakoot district the monthly annual average temperature pattern shows increasing trend with 99% significance. The post-monsoon & winter season shows increasing trend with 99% significance. Annual Sen's Slope estimator also shows 0.019℃ increase in temperature.

Also in Hamirpur district the monthly annual average temperature pattern shows increasing trend with 97% significance. The post-monsoon & winter season shows increasing trend with 99% significance. Annual Sen's Slope estimator also shows 0.053℃ increase in temperature.

Table 3: Z-Value of MK Test for Annual and Seasonal series of Monthly Average Temperature for 102 years

S.No.	Districts	Annual	Pre-Monsoon	Monsoon	Post-Monsoon	Winter
1	Banda	3.60***	1.28	-1.82+	4.90***	4.84***
2	Chitrakoot	3.71***	1.15	-1.80+	5.25***	4.82***
3	Hamirpur	3.24**	1.47	-2.21*	4.25***	4.73***
Significance Level: +90%; *95%; **99%; ***99.9%						





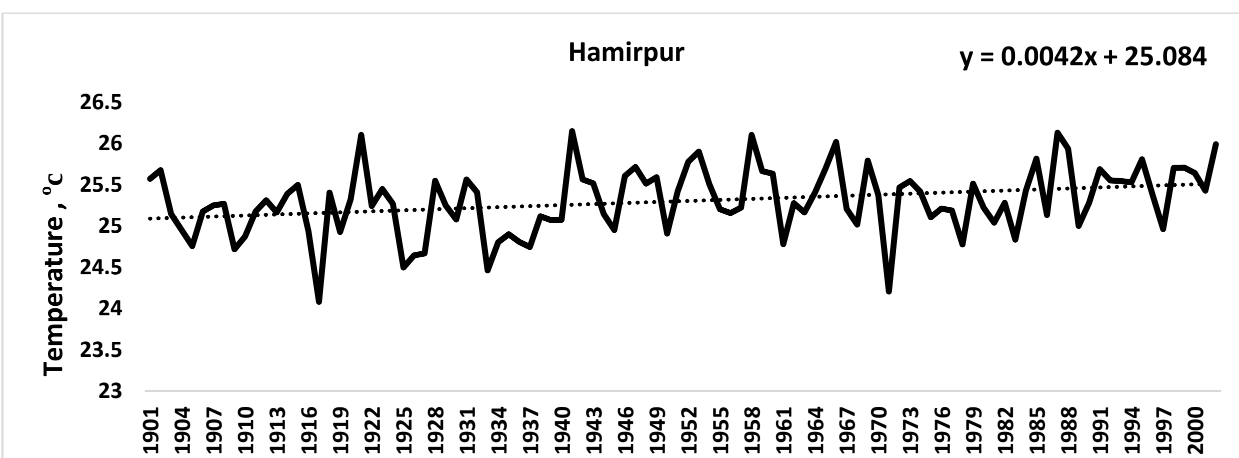
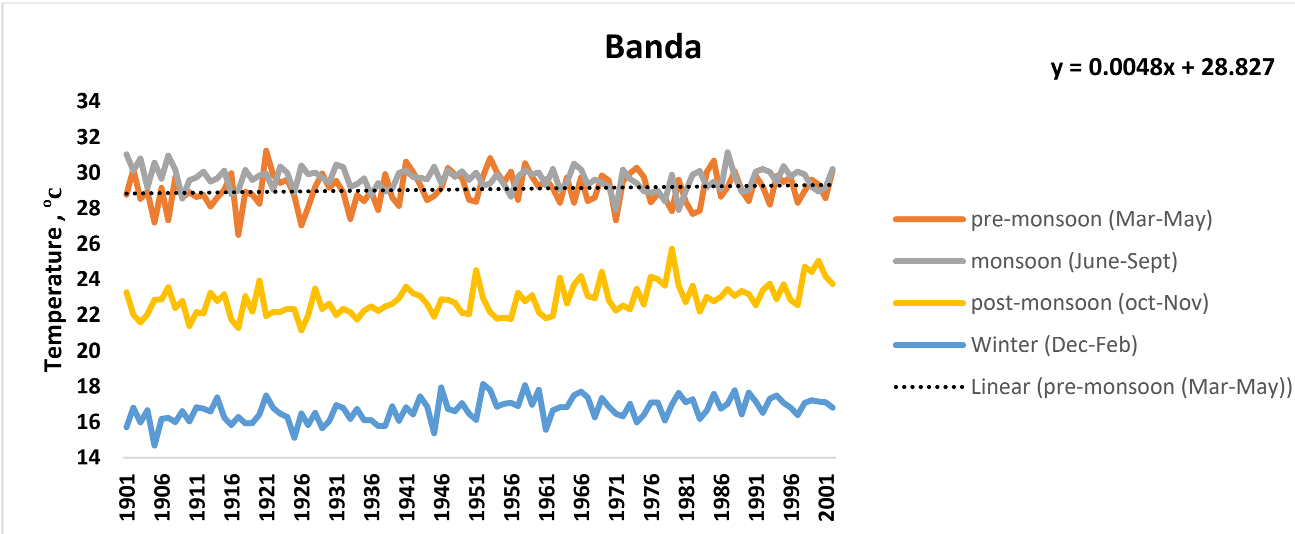
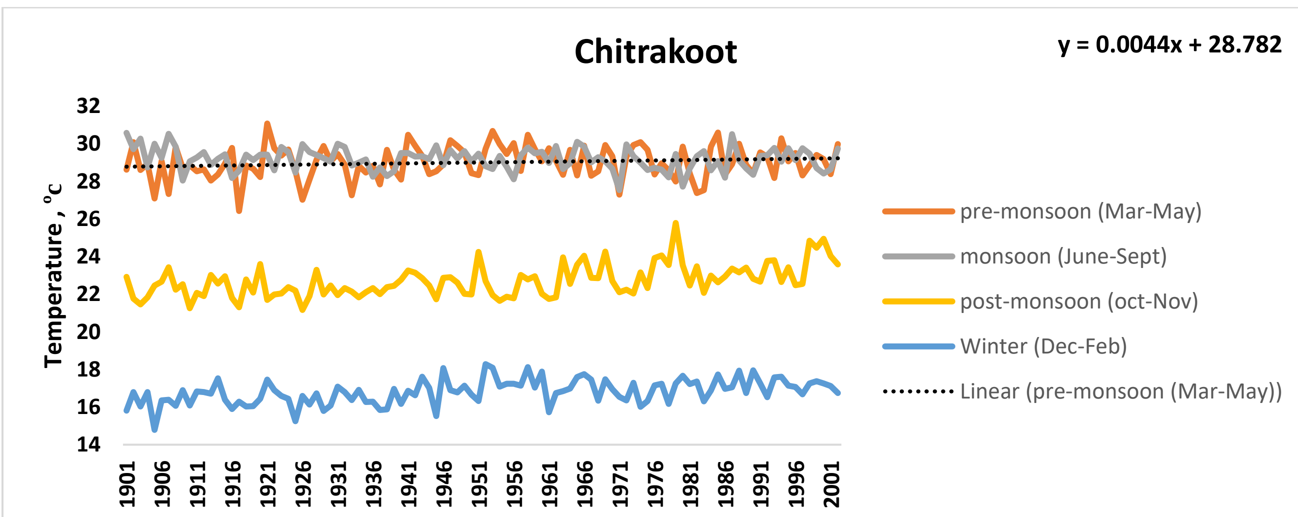


Fig. 4 Linear Trends of Annual Monthly Average Temperature at different district





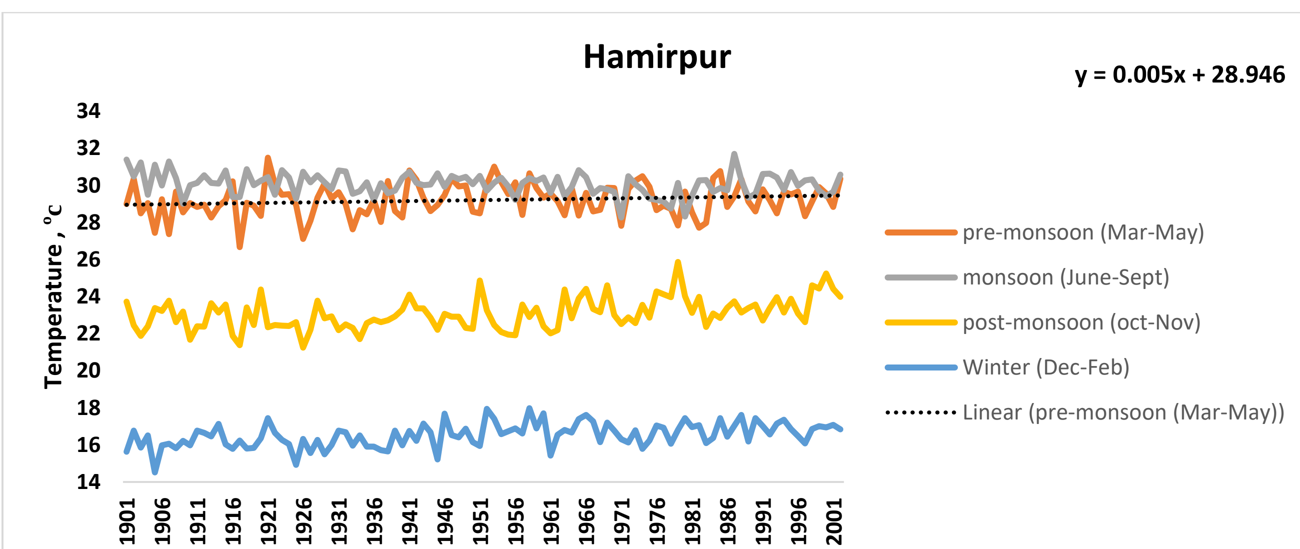


Fig. 5 Linear Trends of Seasonal Monthly Average Temperature at different districts

4.1.3 Reference Evapotranspiration (ETo)

Simple Linear Regression trend has been performed for all the three districts and the results are shown in the Fig.6. From the figures it is evident that one cannot say whether there is ant trend exists in these districts. Inorder to find out the trend with significance level Mann-Kendall test has been applied on the same data.

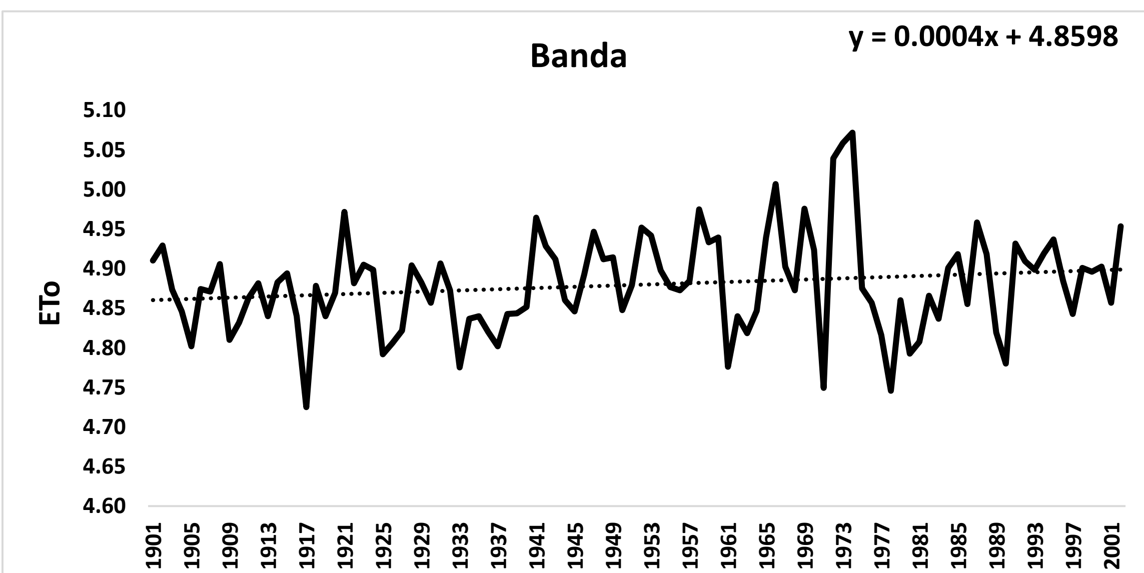
The Reference Evapotranspiration (ETo) was analyzed for a period of 102 years (1901–2002). The results of the MK test for ET_0 are presented in table 4. It can be seen that in Banda district annual Reference Evapotranspiration (ETo) pattern shows increasing trend with 90% significance. The post-monsoon & winter season shows increasing trend with 99% significance. Annual Sen's Slope estimator also shows 0.004 mm/year increase over the years.

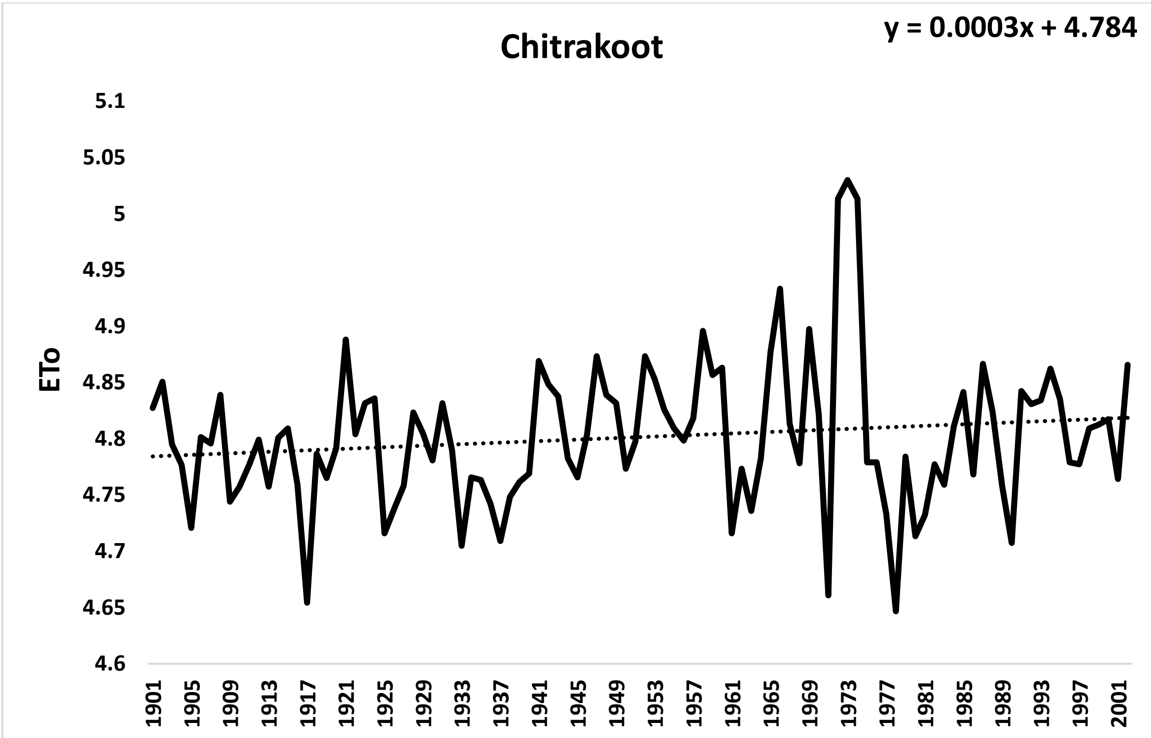
In Chitrakoot district annual Reference Evapotranspiration (ETo) pattern shows increasing trend with non- significance. The post-monsoon & winter season shows increasing trend with 99% significance. Annual Sen's Slope estimator also shows 0.003 mm/year increase over the years.

Also in Hamirpur district annual Reference Evapotranspiration (ETo) pattern shows increasing trend with 90% significance. The post-monsoon & winter season shows increasing trend with 99% significance. Annual Sen's Slope estimator also shows 0.004 mm/year increase over the years.

Table 4: Z-Value of MK Test for Annual and Seasonal series of Reference Evapotranspiration (ETo) for 102 years

S. No.	Districts	Annual	Pre-Monsoon	Monsoon	Post-Monsoon	Winter
1	Banda	1.95+	1.09	-2.08*	4.72***	3.76***
2	Chitrakoot	1.6	0.87	-2.33*	5.04***	3.86***
3	Hamirpur	1.82+	1.27	-2.05*	4.24***	3.71***
Significance Level: +90%; *95%; **99%; ***99.9%						





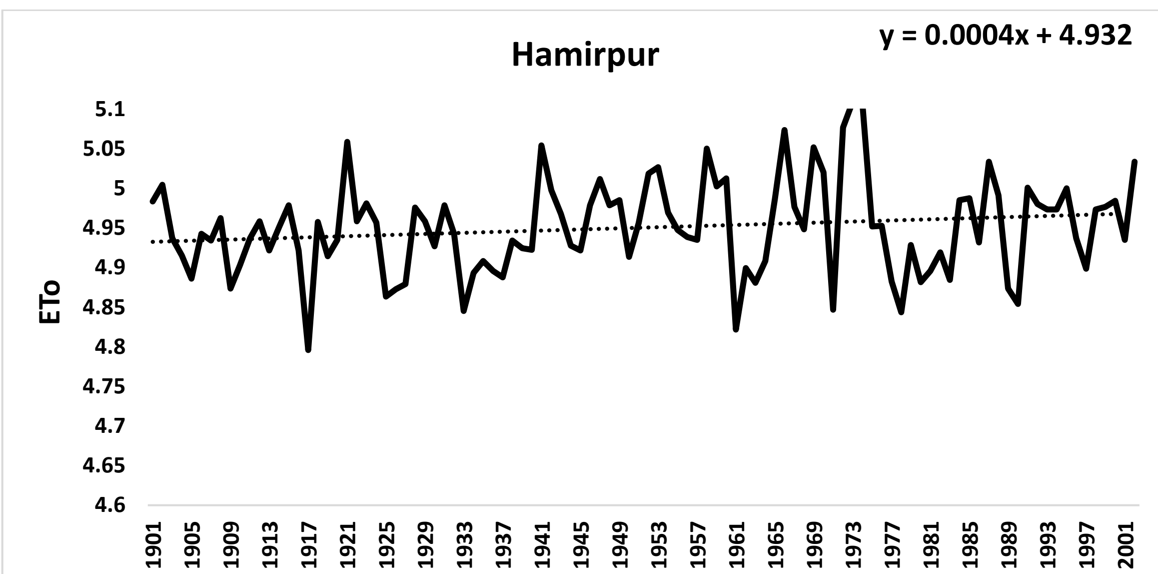


Fig. 6 Linear Trend of Annual Reference Evapotranspiration (ET_0) at different districts

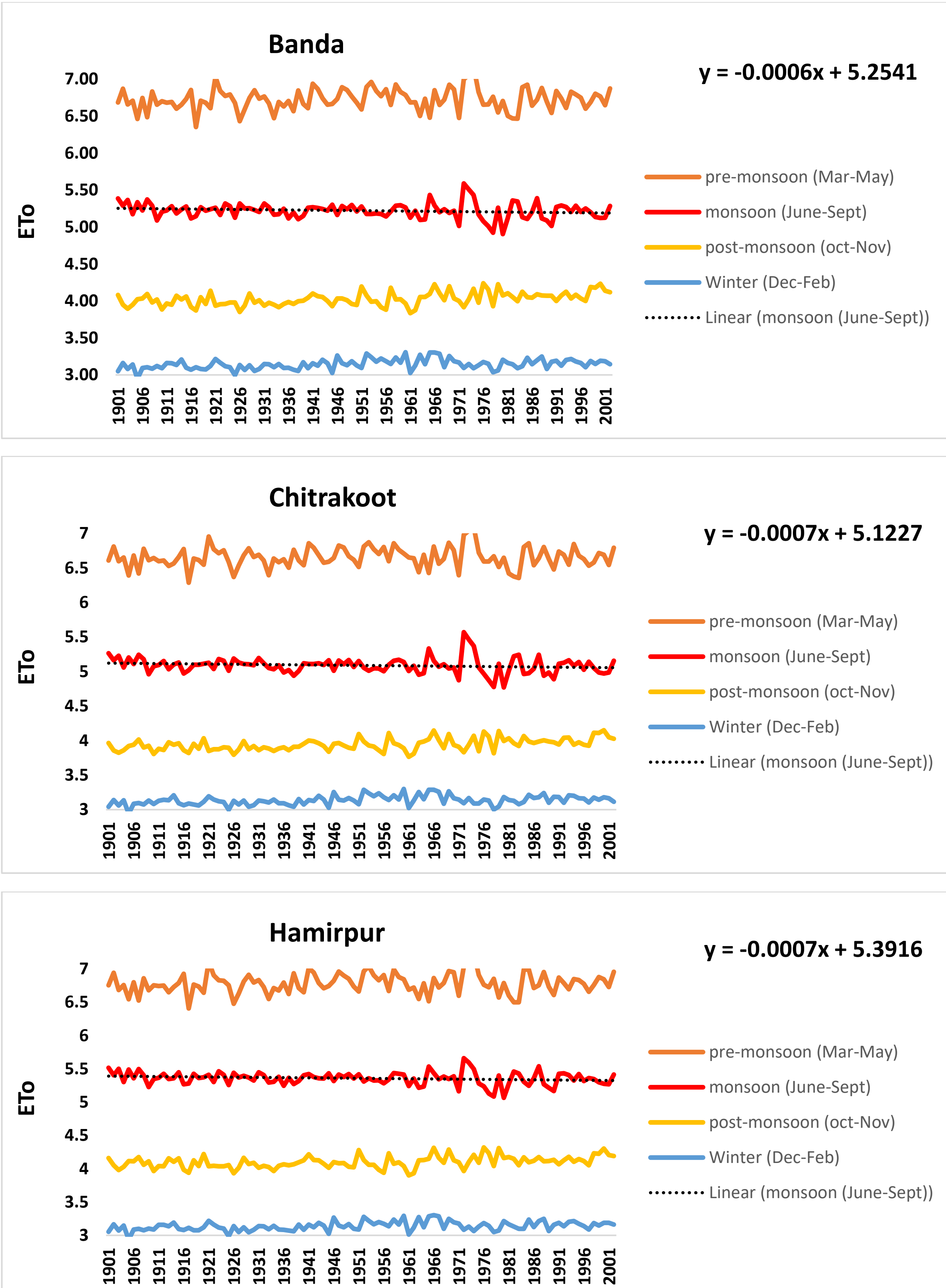


Fig. 7 Linear Trend of Seasonal Reference Evapotranspiration (ET_0) at different districts

4.2. Magnitude of trend

4.2.1 Rainfall

The magnitude of the trend in the rainfall time series, as determined using the Sen Estimator, is given in Tables 5 and 6. The analysis of trends of rainfall variations by districts shows a large variability in the magnitude and direction of trend from one district to another. Monthly analysis of districts rainfall indicated that the districts have very little or no change in non-monsoon months (Table 5).

Table 5: Sen Estimator of slope (mm/year) for monthly rainfall.

S.No.	District	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	Banda	0.07	0.00	0.00	0.00	0.02	0.28	-0.77	-0.60	0.08	0.03	0.00	0.00
2	Chitrakoot	0.09	-0.01	0.00	0.01	0.01	0.35	-0.82	-0.80	0.08	0.03	0.00	0.00
3	Hamirpur	0.03	0.00	0.00	0.00	0.03	0.27	-0.62	-0.19	0.04	0.04	0.00	0.00

On analyzing the estimates of the slope (mm/year) for annual and seasonal rainfall series of all the districts (Table 6), it is implicit that the districts experienced decreasing rainfall in the monsoon season. The maximum reduction was found for Chitrakoot(-0.93 mm/year). The maximum increase out of 3 districts was experienced by Hamirpur in rainfall (0.07 mm/year annually and 0.09 mm/year Monsoon season).

Table 6: Sen Estimator of slope (mm/year) for Annual and seasonal rainfall.

S.No.	Districts	Annual	Pre-Monsoon	Monsoon	Post-Monsoon	Winter
1	Banda	-0.45	0.05	-0.4	0.1	0.07
2	Chitrakoot	-0.84	0.03	-0.93	0.1	0.09
3	Hamirpur	0.07	0.06	0.09	0.13	0.02

4.2.2 Monthly Average Temperature

Mann-Kendall test has confirmed the rising trend in the minimum temperature and no significant trend in maximum temperature, in order to get the rate of rising or fall the magnitude of the trend in the both the temperature series has been determined using the Sen Slope Estimator. The results are given in Tables 7 and 8. The analysis of trends of temperature variations by districts shows variability in the magnitude and direction of trend from one district to another.

On analyzing the estimates of the slope (^{o}C / year) for annual and seasonal maximum temperature series of all the districts from Table 4.7, it is implicit that all the districts experienced increasing max. temperature in the spring and winter season.

The maximum increase was found for Hamirpur (0.014 ^{o}C / year) in spring season. On the other hand, in monsoonal season the same Hamirpur have shown a fall in temperature at the rate of 0.019 ^{o}C / year.

Table 7: Sen Estimator of slope (^{o}C / year) for Annual and seasonal Average Monthly Temperature.

S.No.	Districts	Annual	Pre-Monsoon	Monsoon	Post-Monsoon	Winter
1	Banda	0.005	0.004	-0	0.014	0.009
2	Chitrakoot	0.058	0.01	-0.01	0.029	0.029
3	Hamirpur	0.053	0.014	-0.02	0.024	0.028

4.2.3 Reference Evapotranspiration ETo

The maximum reduction in ETo was found to be same all three districts (-0.003 mm/year) in Monsoon season. The maximum increase was experienced by Banda and Chitrakoot districts in ETo (0.003 m/decade in post-monsoon season).

The magnitude of trend for the ETo for seasonal as well as annual series has been computed and the results are presented in the Table 4.8.

Table 8: Sen Estimator of slope (mm/year) for Annual and seasonal ETo

S.No.	Districts	Annual	Pre-Monsoon	Monsoon	Post-Monsoon	Winter
1	Banda	0.004	0.002	-0.003	0.003	0.002
2	Chitrakoot	0.003	0.001	-0.003	0.003	0.002
3	Hamirpur	0.004	0.002	-0.003	0.002	0.002

.5. Conclusions

This study examined trends in the seasonal and annual rainfall, temperature and evapotranspiration over the Banda district along with adjacent districts viz; Chitrakoot and Hamirpur of the Bundelkhand region. A long term monthly large data set with the length of data series of 102 years has been used for these districts. Most frequently used non-parametric Mann- Kendall test was used to identify the significant trends of rainfall, temperature and evapotranspiration ETo in this study and the magnitude of the trends were ascertained by the well-established Sen's slope estimator method.

In this study, it is found that Reference Evapotranspiration has a significance rise in annual, monsoon, post-monsoon & winter periods in Banda district which implies that there is increase in temperature due to scanty rains which in turn effects the plant growth resulting in low productivity of the crops in the region. The neighbouring districts namely Chitrakoot and Hamirpur considered also experiences the same pattern in the hydrometeorological parameters taken in this study. Also from the graphs it is evident that there is decrease in rainfall trend over the years in all the three districts and increase in monthly average temperature and evapotranspiration ETo trends over the years in all the three districts. The findings in this research paper is quite & well justified with ground realities & atrocities faced by the farmers of the Banda district having frequent drought years.

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