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ORIGINAL RESEARCH ARTICLE

Assessment of long-term climatic variability of Uttarakhand

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ABSTRACT

A trend analysis was performed for historic (1901–2002) climatic variables (Rainfall, Maximum Temperature, and Minimum Temperature) of Uttarakhand State located in Northern India. In the serially independent climatic variables, the Mann-Kendall test (MK test) was applied to the original sample data. However, in the serially correlated series, prewhitening is utilized before employing the MK test. The results of this study indicated a declining trend of rainfall in the monsoon season for seven out of thirteen districts of Uttarakhand state. However, an increasing trend was observed in Haridwar and Udhamsingh Nagar districts for summer season rainfall. For maximum and minimum temperature, a few districts exhibited a declining trend in the monsoon season whereas many districts exhibited an increasing trend in the winter and summer seasons. Mountain dominated areas (as Uttarakhand states) are specific ecosystems, distinguished by their diversity, sensitivity and intricacy. Thus, the variability of rainfall and temperature has a severe and rapid impact on mountainous ecosystems. Nevertheless, mountains have significant impacts on hydrology, which may further threaten populations living in the mountain areas as well as in adjacent, lowland regions.

Keywords: Trend Analysis; Mann-Kendall Test; Climate Change; Uttarakhand State

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1. Introduction

Changing behavior of the hydrological cycle directly affects the availability and quantity of fresh water, which is a major environmental concern of the 21st century[1,2]. As reported by the Intergovernmental Panel on Climate Change (IPCC), the Indian sub-continent will be adversely affected by enhanced variability of climate, rising temperature, and substantial reduction of summer rainfall in some parts, and water stress by 2020[3]. Detection of trends in long-term series of climatic data is of paramount importance and is of practical significance. Studies of change are also of importance because of our need to understand the impact that man is having on the "natural" world[4]. From the statistical point of view, the variability of the climatic parameters can be identified by the presence of statistical evidence of persistence, cycles, trend, and other non-random components.

There are two different approaches to analyzing trends and are classified as parametric method and nonparametric method. Parametric testing procedures are widely used in classical statistics. In parametric testing, it is necessary to assume an underlying distribution for the data (often the normal distribution) and to make assumptions that data observations are independent of one another. For many climatic and hydrological series, these assumptions are not appropriate. Firstly, hydrological series rarely have a normal distribution. Secondly, there is often temporal

dependence in hydrological series. If parametric techniques are to be used, it may be necessary to (a) transform data so that its distribution is nearly normal and (b) restrict analyses to annual series, for which independence assumptions are acceptable, rather than using the more detailed monthly, daily or hourly flow series. In non-parametric and distribution-free methods, fewer assumptions about the data need to be made. With such methods, it is not necessary to assume a distribution. However, many of these methods still rely on assumptions of independence. The most popular nonparametric test for detecting a trend in the time series is Mann-Kendall (MK) test[5,6]. Owing to these facts this study aims at analyzing the persistence and trend of rainfall and minimum and maximum temperature of Uttarakhand State, India. This study could serve as a baseline for the preparation of a sustainable water resources development and management plan for the Uttarakhand State.

2. Materials and methods

2.1 Study area

The Uttrakhand state (**Figure 1**) (28°43' N to 31°27' N and 77°34' E to 81°02' E; 51,125 km^2) is a mountain-dominated state (approximately 90% covered by mountains). The state shares its boundaries with the other Indian states Himachal Pradesh in the northwest and Uttar Pradesh in the South, and with Nepal and China in the southeast and northeast respectively[7]. This Himalayan region has transformed considerably in the recent past, owing to the growth of population (about 10 million) and the resultant increased demand for natural resources in the region. The cultivated land, forests, pastures, and rangelands have deteriorated and depleted steadily and significantly leading to their conversion into degraded and non-productive lands. These rapid land use changes have not only disrupted the fragile ecological equilibrium in the mountains through indiscriminate deforestation, degradation of land resources, and disruption of the hydrological cycle but also have significant and irreversible adverse impacts on the rural economy, and society, livelihood, and life quality of mountain communities.

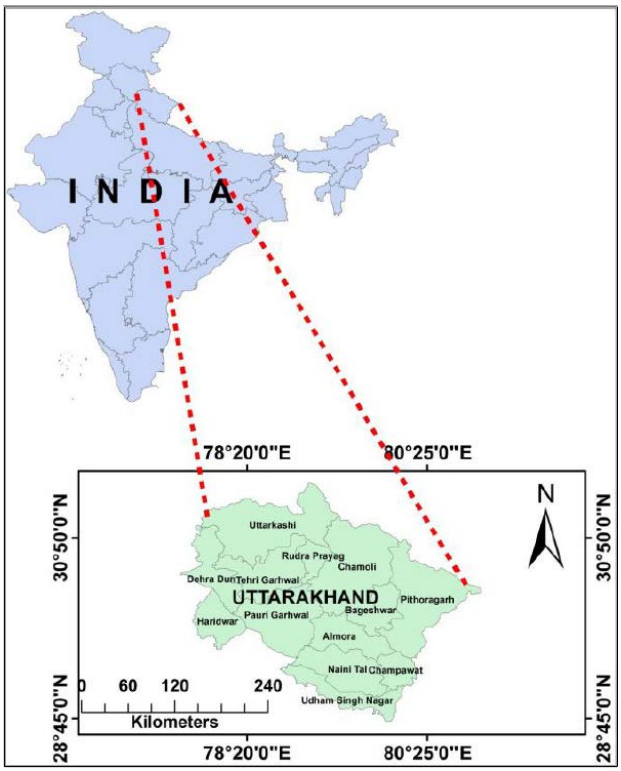

Figure 1. Location map of Uttarakhand state.

2.2 Methodology

The methodology used for the evaluation of trends in hydrological variables for the Uttarakhand state is carried out using the Mann-Kendall non-parametric trend test[5,6]. The following stare eps involved in this study: (i) test the serially correlated or serial-correlated effects of observed climatic data; (ii) if positive serial correlation (persistence) is present in the climatic data, it is removed by pre-whitening; (iii) applying the Mann-Kendall test; (iv) applying Theisel-sen test to get the slope; (v) applying Sen's median estimator to get the relative change.

2.2.1 Persistence

Persistence is also referred to as autocorrelation or serial correlation. As per WMO[8], persistence is a 'tendency for successive values of the series to "remember" their antecedent values, and to be influenced by them.' The approach proposed by WMO[8] and Matalas[9] is widely used in studies related to long-term climatic variations. Several research studies carried out by Rodhe and Virji[10]; Granger[11]; Ogallo[12]; Anyadike[13]; Drosdowsky[14]; Nicholson and Palao[15]; Türkes *et al.*[16] used the approach proposed by WMO[8] and Matalas[9]. Persistence is

evident in long series of climatic observations characterized by a positive serial correlation. Significant negative 1 r is very likely to be indicative of high-frequency oscillations, whereas significant positive 1 r is likely to be indicative of low-frequency fluctuations and persistence in climatic series. To test the persistence in the climatological time series, the normalized anomaly of the time series is used. A normalized series is obtained as follows:

$$X_t = (x_t - \bar{x})/\sigma \tag{1}$$

Where X_t is the normalized anomaly of the series, x_t is the observed time series, $\bar{x}$ and σ is the long-term mean and standard deviation of annual/seasonal time series. All serial correlation coefficients of normalized climatic series are computed for lags $L = 0$ to m, where m is the maximum lag (i.e. $= n/3$); n is the length of the series. The serial correlation coefficient was computed from equation 2.

$$r_L = \frac{\sum_{t=1}^{n-L}(X_t - \bar{X}_t)\cdot(X_{t+L} - \bar{X}_{t+L})}{\left[\sum_{t=1}^{n-L}(X_t - \bar{X}_t)^2 \cdot \sum_{t=1}^{n-L}(X_{t+L} - \bar{X}_{t+L})^2\right]^{1/2}} \tag{2}$$

To test the significance of serial correlation, equation 3 is used[17].

$$r_k = \frac{-1 \pm t_g\,(n-k-1)^{1/2}}{n-k} \tag{3}$$

Where t_g = 1.645, 4.965, 2.326 are at 90, 95, and 99 percent confidence intervals, respectively. The "null" hypothesis of the randomness of climatic series against the serial correlation is rejected for the large value of r_1. If r_1 does not significantly differ from zero, then the series is regarded to be free from persistence. In this case, the appropriate null continuum is termed "white noise". However, in the study, serial correlation coefficients up to lag-3 were assessed[7].

2.2.2 Original Mann-Kendall

The MK test also called Kendall's tau test due to Mann[5] and Kendall[6], is the rank-based nonparametric test for assessing the significance of a trend and has been widely used in hydrological trend detection studies. It is based on the test statics S defined as below:

$$S = \sum_{i=1}^{n-1}\sum_{j=i+1}^{n} \operatorname{sgn}(x_j - x_i) \tag{4}$$

Where, $x_1, x_2, \ldots x_n$ represent n data points where x_j represents the data point at time j.

A very high positive value of S is an indicator of an increasing trend, and a very low negative value indicates a decreasing trend.

$$\operatorname{sgn}(x_j - x_i) = \begin{cases} 1 \ldots\ldots\ldots \text{if } (x_j - x_i) > 0 \\ 0 \ldots\ldots\ldots \text{if } (x_j - x_i) = 0 \\ -1 \ldots\ldots\ldots \text{if } (x_j - x_i) < 0 \end{cases} \tag{5}$$

It has been documented that when $n \geq 10$, the statistic S is approximately normally distributed with the mean

$E(S) = 0$

And its variance is

$$\mathrm{VAR}(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i-1)(2t_i+5)}{18} \tag{6}$$

Where n is the number of data points, m is the number of tied groups (a tied group is a set of sample data having the same value), and t_i is the number of data points in the i^{th} group.

The standardized test statistic Z is computed as follows:

$$Z = \begin{cases} \frac{S-1}{\sqrt{\mathrm{VAR}(S)}} & \text{if } S > 0 \\ 0 \text{ if } S = 0 \\ \frac{S+1}{\sqrt{\mathrm{VAR}\,(S)}} & \text{if } S < 0 \end{cases} \tag{7}$$

The null hypothesis, H_0, meaning that no significant trend is present, is accepted if the test statistic Z is not statistically significant, i.e. $-Z_{\alpha/2} < Z < Z_{\alpha/2}$, where $Z_{\alpha/2}$ is the standard normal deviate. In this study, three different significance levels i.e., 1%, 5%, and 10% were considered.

2.2.3 Mann-Kendall test with pre-whitening

Several approaches have been suggested for removing the serial correlation from a data set prior to applying the test. The pre-whitening approach is

most common which involves computation of serial correlation and removing the correlation if the calculated serial correlation is significant at a 5% significance level as suggested by Burn and Hag Elnur[18].

The MK test with the prewriting procedure suggested by Yue *et al.*[19] is applied in the following manner to detect a significant trend in a serially correlated time series.

(1) The slope (β) of a trend in sample data is estimated using the approach proposed by Theil[20] and Sen[21].

The original sample data X_t was unitized by dividing each of their values with the sample mean E (X_t) prior to conducting the trend analysis[19]. By this treatment, the mean of each data set is equal to one and the properties of the original sample data remain unchanged. If the slope is almost equal to zero, then it is not necessary to continue to conduct trend analysis. If it differs from zero, then it is assumed to be linear, and the sample data are de-trended by:

$$X'_t = X_t - T_t = X_t - \beta \cdot t \quad (8)$$

(2) The lag-1 serial correlation coefficient (r_1) of the de-trended series X_t is computed using Equation (6.8). If r_1 is not significantly different from zero, the sample data are considered to be serially independent and the MK test is directly applied to the original sample data. Otherwise, it is considered to be serially correlated and AR (1) is removed from the X'_t by

$$Y'_t = X'_t - r_1 \cdot X'_{t-1} \quad (9)$$

This pre-whitening procedure after de-trending the series is referred to as the trend-free pre-whitening (TFPW) procedure. The residual series after applying the TFPW procedure should be an independent series.

(3) The identified trend (T_t) and the residual Y'_t are combined as:

$$Y_t = Y'_t + T_t \quad (10)$$

The blended series (Y'_t) just includes a trend and a noise and is no longer influenced by serial correlation. Then the MK test is applied to the blended series to assess the significance of the trend.

2.2.4 Slope

Slope of the lines fit to the time series of climatic data provides a picture of changes that have occurred at any location over an extended period. The slope of the data set can be estimated using the Thiel-Sen Approach. This equation is used instead of a linear regression because it limits the influence that the outliers have on the slope[22].

$$\beta = Median\left[\frac{X_j - X_i}{j-i}\right] \quad For\ all\ i < j \quad (11)$$

where X_j and X_i are data values at times j and i ($i > j$), respectively.

2.2.5 Relative change

To compute the relative change of different climatic parameters, the following equation was used.

$$RC = \frac{n * \beta}{|x|} * 100 \quad (12)$$

Where, n is the length of trend period (years), β is the magnitude of the trend slope of the time series which is determined by Sen's median estimator, and $|x|$ is the absolute average value of the time series.

2.3 Data requirements

To study the climatic variability, district level Monthly Rainfall (1901 to 2002) and Monthly Maximum and Minimum Temperature (1901 to 2002) were considered for 13 districts of Uttarakhand state. These data were collected from India Water Portal website (http://www.indiawaterportal.org/).

3. Result and discussion

The present study was conducted to analyze the variability of rainfall, maximum temperature and minimum temperature for Uttarakhand state on seasonal and annual time step. For seasonal analysis, the year was classified into water year (three seasons, each of 4 months duration). Season 1 corresponds to the monsoon season (June–September), season 2 corresponds to the winter season (October–January)

and season 3 corresponds to the winter season (February–May). A non-parametric test (Man-Kendall test) was used in this study. The climatic variables were tested for persistence. In case of station exhibiting significant persistence, pre-whitening test is carried out prior to trend analysis to eliminate the effect of serial correlation. Trend analysis was carried out at 1, 5 and 10% significance level.

3.1 Rainfall

The trend was analyzed for a period of (1901–2002). In season 1 for Almora (**Table 1**) it can be observed that there is a decreasing trend in rainfall. The sen slope for monsoon season was -1.51 while the relative change was found to be -15.87. In season 2 there was no significant trend was found. The sen slope was -0.13 and relative change was -18.26. In season 3 no significant trend was found. The sen slope was 0.15 and relative change was 16.62 in yearly there was no significant trend was found. The sen slope was -1.93 and relative change was -14.94.

Table 1. Serial correlation analysis and trend analysis for rainfall for Almora District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	-0.1358	-1.8221	-10	-1.5157	1058.185	-15.8735
Season 2	0.2078	-0.8715	0	-0.1385	56.981	-18.2685
Season 3	0.0545	1.1942	0	0.1552	81.741	16.6272
Yearly	-0.1238	-1.517	0	-1.9395	1414.692	-14.9449

Table 2. Serial correlation analysis and trend analysis for rainfall for Bageshwar District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	-0.1228	-1.8221	-10	-1.5157	1058.185	-15.8735
Season 2	0.2044	-0.8715	0	-0.1385	56.981	-18.2685
Season 3	0.0222	1.1942	0	0.1552	81.741	16.6272
Yearly	-0.1297	-1.517	0	-1.9395	1414.692	-14.9449

The trend was analyzed for a period of (1901–2002). In season 1 for Bageshwar (**Table 2**), it can be observed that there is a decreasing trend in rainfall. The sen slope for monsoon season was -15.15 while the relative change was found to be -15.87. In season 2 there was no significant trend was found the sen slope was -0.13 and relative change was -18.26. In season 3 no significant trend was found the sen slope was 0.15 and relative change was 16.62 in yearly there was no significant trend was found the sen slope was -1.93 and relative change was -14.94.

Table 3. Serial correlation analysis and trend analysis for rainfall for Chamoli District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	-0.1612	-1.8456	-10	-2.150	-18.4267	-15.8735
Season 2	0.2397	-1.0416	0	-0.2067	84.171	-18.2685
Season 3	-0.0432	0.6719	0	0.1381	140.2314	16.6272
Yearly	-0.1342	-1.3937	0	-1.3550	-12.0807	-14.9449

The trend was analyzed for a period of (1901–2002). In season 1 for Chamoli (**Table 3**) it can be observed that there is a decreasing trend in rainfall. The sen slope for monsoon season was -2.155 while the relative change was found to be -15.87. In season 2 there was no significant trend was found the sen slope was -0.20 and relative change was -18.26 In season 3 no significant trend was found the sen slope was 0.13 and relative change was 16.62 in yearly there was no significant trend was found the sen slope was -1.35 and relative change was -14.94.

The trend was analyzed for a period of (1901–2002). In season 1 for Champawat (**Table 4**) it can be observed that there is a decreasing trend in rainfall. The sen slope for monsoon season was -3.08 while the relative change was found to be -21.84. In season 2 there was no significant trend was found the sen slope was -0.10 and relative change was -13.67 In season 3 no significant trend was found the sen slope was 0.13 and relative change was 15.32 in yearly there is a decreasing trend was

found the sen slope was -2.49 and relative change was -17.60

Table 5. Serial correlation analysis and trend analysis for rainfall for Dehradun District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	-0.121	-1.7517	-10	-1.5681	1017.601	-16.975
Season 2	0.2077	-0.76	0	-0.0964	47.9003	-14.6333
Season 3	0.0688	1.4876	0	0.154	64.1587	20.6739
Yearly	-0.1193	-1.6813	-10	-1.5155	1167.304	-14.2409

The trend was analyzed for a period of (1901−2002). In season 1 for Dehradun (**Table 5**) it can be observed that there is a decreasing trend in rainfall. The sen slope for monsoon season was -1.56 while the relative change was found to be -1697. In season 2 there was no significant trend was found the sen slope was -0.09 and relative change was -14.63 In season 3 no significant trend was found the sen slope was 0.15 and relative change was 20.67 in yearly there is a decreasing trend was found the sen slope was -1.51 and relative change was -14.24.

The trend was analyzed for a period of (1901−2002). In season 1 for Garhwal (**Table 6)**, it can be observed that there was no significant trend in rainfall. The sen slope for monsoon season was -0.78 while the relative change was found to be -9.30. In season 2 there was no significant trend was found the sen slope was -0.12 and relative change was -19.40 In season 3 no significant trend was found the sen slope was 0.16 and relative change was 20.42 in yearly no significant trend was found the sen slope was -0.75 and relative change was -5.93.

Table 5. Serial correlation analysis and trend analysis for rainfall for Dehradun District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	-0.121	-1.7517	-10	-1.5681	1017.601	-16.975
Season 2	0.2077	-0.76	0	-0.0964	47.9003	-14.6333
Season 3	0.0688	1.4876	0	0.154	64.1587	20.6739
Yearly	-0.1193	-1.6813	-10	-1.5155	1167.304	-14.2409

Table 6. Serial correlation analysis and trend analysis for rainfall for Garhwal District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	-0.1874	-1.0182	0	-0.7839	1050.722	-9.3044
Season 2	0.1952	-0.9771	0	-0.1234	48.8094	-19.4052
Season 3	0.0618	1.5111	0	0.1664	72.1954	20.4264
Yearly	-0.1549	-0.6837	0	-0.7544	1320.415	-5.933

The trend was analyzed for a period of (1901−2002). In season 1 for Hardwar (**Table 7**) it can be observed that there was no significant trend in rainfall. The sen slope for monsoon season was 0.23 while the relative change was found to be 3.39. In season 2 there was no significant trend was found the sen slope was -0.07 and relative change was -13.38 In season 3 there was increasing trend found the sen slope was 0.17 and relative change was 26.76 in yearly no significant trend was found the sen slope was -0.38 and relative change was 3.90.

The trend was analyzed for a period of (1901−2002). In season 1 for Nainital (**Table 8**) it can be observed that there was decreasing trend in rainfall. The sen slope for monsoon season was -1.56 while the relative change was found to be -16.97. In season 2 there was no significant trend was found the sen slope was -0.09 and relative change was -14.63 In season 3 there was increasing trend found the sen slope was 0.15 and relative change was 20.67 in yearly there was decreasing trend was found the sen slope was -1.51 and relative change was -14.24.

The trend was analyzed for a period of (1901−2002). In season 1 for Pithodagar (**Table 9**) it can be observed that there was decreasing trend in rainfall. The sen slope for monsoon season was -1.67 while the relative change was found to be -17.56. In season 2 there was no significant trend was found the sen slope was -0.17 and relative change

was -16.32. In season 3 there was increasing trend found the sen slope was 0.14 and relative change was 8.45 in yearly there was decreasing trend was found the sen slope was -1.91 and relative change was -15.09.

Table 7. Serial correlation analysis and trend analysis for rainfall for Haridwar District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	-0.2018	0.355	0	0.2369	853.2654	3.3954
Season 2	0.1444	-0.7512	0	-0.0707	54.3734	-13.3885
Season 3	0.1038	1.9571	10	0.173	57.1172	26.7639
Yearly	-0.0035	0.5252	0	0.3813	949.9835	3.9017

Table 8. Serial correlation analysis and trend analysis for rainfall for Nainital District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	-0.121	-1.7517	-10	-1.5681	1017.601	-16.975
Season 2	0.2077	-0.76	0	-0.0964	47.9003	-14.6333
Season 3	0.0688	1.4876	0	0.154	64.1587	20.6739
Yearly	-0.1193	-1.6813	-10	-1.5155	1167.304	-14.2409

Table 9. Serial correlation analysis and trend analysis for rainfall for Pithodagar District

Season	r_1	ZMK	Trend	Sen slope	Intercept	relative change
Season 1	-0.0931	-1.9747	-5	-1.6767	1057.788	-17.567
Season 2	0.2457	-0.7952	0	-0.1774	79.2775	-16.3269
Season 3	-0.0059	0.6426	0	0.1451	158.3344	8.4525
Yearly	-0.1124	-2.1273	-5	-1.9153	1339.953	-15.0913

The trend was analyzed for a period of (1901–2002). In season 1 for Rudrapryag (**Table 10**) it can be observed that there was no significant trend in rainfall. The sen slope for monsoon season was -1.16 while the relative change was found to be -13.36. In season 2 there was no significant trend was found the sen slope was -0.17 and relative change was -18.84. In season 3 no significant trend found the sen slope was 0.14 and relative change was 9.94 in yearly there was no significant trend was found the sen slope was -1.05 and relative change was -9.55.

Table 10. Serial correlation analysis and trend analysis for rainfall for Rudraprayag District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	-0.1089	-1.5023	0	-1.1605	926.194	-13.3603
Season 2	0.2323	-0.9771	0	-0.171	72.2283	-18.8451
Season 3	-0.059	0.8245	0	0.1407	133.0556	9.9485
Yearly	-0.1338	-1.206	0	-1.0516	1161.76	-9.5537

The trend was analyzed for a period of (1901–2002). In season 1 for Tiharigarwal (**Table 11**) it can be observed that there was no significant trend in rainfall. The sen slope for monsoon season was -076 while the relative change was found to be -9.04. In season 2 there was no significant trend was found the sen slope was -0.13 and relative change was -19.43. In season 3 no significant trend found the sen slope was 0.18 and relative change was 15.95 in yearly there was no significant trend was found the sen slope was -0.57 and relative change was -5.64.

The trend was analyzed for a period of (1901–2002). In season 1 for Utham Singh Nager (**Table 12**) it can be observed that there was no significant trend in rainfall. The sen slope for monsoon season was -1.03 while the relative change was found to be -11.89. In season 2 there was no significant trend was found the sen slope was -0.07 and relative change was -12.52. In season 3 there was increasing trend found the sen slope was 0.16 and relative change was 24.97 in yearly there was no significant trend was found the sen slope was -0.86 and relative change was 10.70.

Table 11. Serial correlation analysis and trend analysis for rainfall for Tihrigarwal District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	-0.1591	-1.0299	0	-0.7629	890.4837	-9.0429
Season 2	0.1944	-1.0123	0	-0.1389	60.9164	-19.4369
Season 3	0.0213	1.206	0	0.1834	103.7123	15.9538
Yearly	-0.1635	-0.76	0	-0.5724	1045.566	-5.6473

Table 12. Serial correlation analysis and trend analysis for rainfall for Udham Singh NagerDistrict

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	-0.1369	-1.2999	0	-1.0352	943.3654	-11.8998
Season 2	0.2211	-0.6719	0	-0.078	42.1054	-12.5243
Season 3	0.074	1.7165	10	0.1631	56.1379	24.9779
Yearly	-0.1327	-1.1238	0	-0.8677	-8.6984	10.7058

The trend was analyzed for a period of (1901–2002). In season 1 for Uttarkashi (**Table 13**) it can be observed that there was no significant trend in rainfall. The sen slope for monsoon season was -0.88 while the relative change was found to be -11.26. In season 2 there was no significant trend was found the sen slope was -0.14 and relative change was -17.32. In season 3 no significant trend found the sen slope was 0.19 and relative change was 14.89 in yearly there was no significant trend was found the sen slope was -0.67 and relative change was-15.51.

Table 13. Serial correlation analysis and trend analysis for rainfall for Uttarkashi District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	-0.0742	-1.2294	0	-0.8856	820.6787	-11.2603
Season 2	0.2117	-1.1238	0	-0.1442	72.5596	-17.3201
Season 3	-0.0684	1.1297	0	0.1954	114.7676	14.8911
Yearly	-0.1097	-0.8362	0	-0.6799	1035.254	-15.5107

3.2 Maximum temperature

The trend was analyzed for a period of (1901–2002). In season 1 for Almora (**Table 14**) it can be observed that there was no significant trend in rainfall. The sen slope for monsoon season was -0.0026 while the relative change was found to be -0.79. In season 2 there was no significant trend was found the sen slope was -0.0042 and relative change was 1.71. In season 3 there was increasing trend found the sen slope was 0.0063 and relative change was 2.06 in yearly there was no significant trend was found the sen slope was -0.0012 and relative change was-0.40.

Table 14. Serial correlation analysis and trend analysis for maximum temperature for Almora District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	0.2052	.5229	0	-0.0026	26.8665	-0.7912
Season 2	0.3664	1.517	0	0.0042	15.4856	1.717
Season 3	0.0895	1.8251	10	0.0063	30.8373	2.0601
Yearly	0.3271	0.6367	0	0.0012	20.0432	0.4075

The trend was analyzed for a period of (1901–2002). In season 1 for Bageshwar (**Table 15**) it can be observed that there was no significant trend in rainfall. The sen slope for monsoon season was -0.0021 while the relative change was found to be -0.706. In season 2 there was increasing trend was found the sen slope was 0.0052 and relative change was 2.39. In season 3 there was increasing trend found the sen slope was 0.0068 and relative change was 2.51 in yearly there was no significant trend was found the sen slope was 0.0017 and relative change was 0.64.

The trend was analyzed for a period of (1901–2002). In season 1 for Chamoli (**Table 16**) it can be observed that there was no significant trend in rainfall. The sen slope for monsoon season was -0.0018 while the relative change was found to be -0.71. In season 2 there was increasing trend was

found the sen slope was 0.0059 and relative change was 3.34. In season 3 there was increasing trend found the sen slope was 0.0075 and relative change was 3.38 in yearly there was no significant trend was found the sen slope was 0.0013 and relative change was 0.59.

Table 15. Serial correlation analysis and trend analysis for maximum temperature Bageshwar District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	0.2322	-1.2764	0	-0.0021	23.1663	-0.706
Season 2	0.3694	1.8339	10	0.0052	13.4495	2.39
Season 3	0.0957	2.0099	5	0.0068	26.9239	2.5152
Yearly	0.3484	0.983	0	0.0017	17.082	0.6495

Table 16. Serial correlation analysis and trend analysis for maximum temperature for Chamoli District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	0.2476	-1.1825	0	-0.0018	19.518	-0.7141
Season 2	0.3793	1.9982	5	0.0059	10.7106	3.3418
Season 3	0.0907	2.2799	5	0.0075	21.9611	3.3861
Yearly	0.4303	0.8597	0	0.0013	12.7265	0.5915

The trend was analyzed for a period of (1901–2002). In season 1 for Champawat (**Table 17**) it can be observed that there was no significant trend in rainfall. The sen slope for monsoon season was -0.0022 while the relative change was found to be -0.56. In season 2 there was increasing trend was found the sen slope was 0.0046 and relative change was 1.79. In season 3 there was increasing trend found the sen slope was 0.0065 and relative change was 2.01 in yearly there was no significant trend was found the sen slope was 0.0015 and relative change was 0.50.

Table 17. Serial correlation analysis and trend analysis for maximum temperature for Champawat District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	0.2074	-1.4524	0	-0.0022	27.4675	-0.6564
Season 2	0.3546	1.7752	10	0.0046	16.4975	1.7981
Season 3	0.0991	1.8544	10	0.0065	32.1861	2.0159
Yearly	0.3264	0.9595	0	0.0015	20.7807	0.5032

The trend was analyzed for a period of (1901–2002). In season 1 for Dehradun (**Table 18**) it can be observed that there was decreasing trend in rainfall. The sen slope for monsoon season was -0.0042 while the relative change was found to be -1.22. In season 2 no significant trend was found the sen slope was 0.0032 and relative change was 1.27. In season 3 there was increasing trend found the sen slope was 0.0083 and relative change was 2.69 in yearly there was no significant trend was found the sen slope was 0.0013 and relative change was 0.42.

Table 18. Serial correlation analysis and trend analysis for maximum temperature Dehradun District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	0.1935	-2.1566	-5	-0.0042	28.2384	-1.2258
Season 2	0.3409	1.3292	0	0.0032	16.3774	1.2789
Season 3	0.1008	2.4911	1	0.0083	30.6869	2.6955
Yearly	0.2917	0.801	0	0.0013	21.458	0.4287

The trend was analyzed for a period of (1901–2002). In season 1 for Garwal (**Table 19**) it can be observed that there was decreasing trend in rainfall. The sen slope for monsoon season was -0.0034 while the relative change was found to be -0.99. In season 2 no significant trend was found the sen slope was 0.0042 and relative change was 1.67. In season 3 there was increasing trend found the sen slope was 0.0069 and relative change was 2.22 in yearly there was no significant trend was found the sen slope was 0.0011 and relative change was 0.36.

The trend was analyzed for a period of (1901–2002). In season 1 for Hardwar (**Table 20**)

it can be observed that there was decreasing trend in rainfall. The sen slope for monsoon season was -0.0056 while the relative change was found to be -1.62. In season 2 no significant trend was found the sen slope was 0.0038 and relative change was 1.49. In season 3 there was increasing trend found the sen slope was 0.0079 and relative change was 2.50 in yearly there was no significant trend was found the sen slope was 0.0016 and relative change was 0.52.

Table 19. Serial correlation analysis and trend analysis for maximum temperature for Garwal District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	0.1612	-2.0686	-5	-0.0034	28.7206	-0.9954
Season 2	0.3711	1.6285	0	0.0042	15.473	1.6771
Season 3	0.0903	1.9865	5	0.0069	30.9591	2.2253
Yearly	0.3069	0.8539	0	0.0011	20.8239	0.367

Table 20. Serial correlation analysis and trend analysis for maximum temperature for Haridwar District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	0.129	-2.8286	-1	-0.0056	35.2652	-1.62
Season 2	0.3605	1.6226	0	0.0038	16.1702	1.4902
Season 3	0.1031	2.4559	1	0.0079	31.2375	2.5099
Yearly	0.267	0.7893	0	0.0016	22.4635	0.5239

The trend was analyzed for a period of (1901–2002). In season 1 for Nainital (**Table 21**) it can be observed that there was decreasing trend in rainfall. The sen slope for monsoon season was -0.0031 while the relative change was found to be -091. In season 2 there was increasing trend was found the sen slope was 0.0042 and relative change was 1.64. In season 3 there was increasing trend found the sen slope was 0.0064 and relative change was 2.00 in yearly there was no significant trend was found the sen slope was 0.0011 and relative change was 0.35

Table 21. Serial correlation analysis and trend analysis for maximum temperature for Nainital District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	0.1766	-1.8045	-10	-0.0031	28.6573	-0.9132
Season 2	0.3674	1.7693	10	0.0042	16.1001	1.6413
Season 3	0.0868	1.875	10	0.0064	32.2123	2.0029
Yearly	0.313	0.7424	0	0.0011	21.2796	0.3545

The trend was analyzed for a period of (1901–2002). In season 1 for Pithodagar (**Table 22**) it can be observed that there was no significant trend in rainfall. The sen slope for monsoon season was -0.0014 while the relative change was found to be -0.52. In season 2 there was increasing trend was found the sen slope was 0.0065 and relative change was 3.60. In season 3 there was increasing trend found the sen slope was 0.0073 and relative change was 1.17 in yearly there was no significant trend was found the sen slope was 0.0026 and relative change was 0.35.

Table 22. Serial correlation analysis and trend analysis for maximum temperature Pithodagar District

Season	r_1	ZMK	Trend	Sen slope	Intercept	relative change
Season 1	0.2491	-0.7834	0	-0.0014	19.7754	-0.5268
Season 2	0.3548	2.186	5	0.0065	11.3044	3.6092
Season 3	0.0961	2.3884	1	0.0073	22.3828	3.2587
Yearly	0.3473	1.5698	0	0.0026	14.441	1.1776

The trend was analyzed for a period of (1901–2002). In season 1 for Rudraprayag (**Table 23**) it can be observed that there was no significant trend in rainfall. The sen slope for monsoon sea-son was -0.003 while the relative change was found to be -0.92. In season 2 there was no significant trend was found the sen slope was 0.0041 and relative change was 1.76. In season 3 there was increasing trend found the sen slope was 0.0075 and relative change was 2.57 in yearly there was no significant trend was

found the sen slope was 0.0015 and relative change was 0.51.

The trend was analyzed for a period of (1901-2002). In season 1 for Tiharigarwal (**Table 24**) it can be observed that there was no significant trend in rainfall. The sen slope for monsoon season was -0.003 while the relative change was found to be -0.92. In season 2 there was no significant trend was found the sen slope was 0.0041 and relative change was 1.76. In season 3 there was increasing trend found the sen slope was 0.0075 and relative change was 2.57 in yearly there was no significant trend was found the sen slope was 0.0015 and relative change was 0.51.

The trend was analyzed for a period of (1901–2002). In season 1 for Utham Singh Nager (**Table 25**) it can be observed that there was decreasing trend in rainfall. The sen slope for monsoon season was -0.0044 while the relative change was found to be 1.28. In season 2 there was increasing trend was found the sen slope was 0.0044 and relative change was 1.68. In season 3 there was no significant trend found the sen slope was 0.0054 and relative change was 1.60 in yearly there was no significant trend was found the sen slope was 0.0024 and relative change was 0.79.

Table 23. Serial correlation analysis and trend analysis for maximum temperature Rudraprayag District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	0.1979	-1.5874	0	-0.003	26.307	-0.9237
Season 2	0.3577	1.5639	0	0.0041	14.8321	1.7658
Season 3	0.0908	2.2388	5	0.0075	28.953	2.5773
Yearly	0.3223	0.9125	0	0.0015	19.2476	0.5198

Table 24. Serial correlation analysis and trend analysis for maximum temperature Tiharigarwal District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	0.1979	-1.5874	0	-0.003	26.307	-0.9237
Season 2	0.3577	1.5639	0	0.0041	14.8321	1.7658
Season 3	0.0908	2.2388	5	0.0075	28.953	2.5773
Yearly	0.3223	0.9125	0	0.0015	19.2476	0.5198

Table 25. Serial correlation analysis and trend analysis for maximum temperature for Udham SinghNager District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	0.137	-2.6467	-1	-0.0044	35.0165	-1.282
Season 2	0.3675	1.8926	10	0.0044	16.2194	1.6833
Season 3	0.0547	1.605	0	0.0054	33.9421	1.605
Yearly	0.3222	1.3527	0	0.0024	20.1978	0.7978

The trend was analyzed for a period of (1901-2002). In season 1 for Uttarkashi (**Table 26**) it can be observed that there was no significant trend in rainfall. The sen slope for monsoon season was -0.0021 while the relative change was found to be -0.81. In season 2 there was increasing trend was found the sen slope was 0.0044 and relative change was 2.53. In season 3 there was increasing trend found the sen slope was 0.0083 and relative change was 3.84 in yearly there was no significant trend was found the sen slope was 0.0024 and relative change was 1.12.

Table 26. Serial correlation analysis and trend analysis for maximum temperature for Uttarkashi District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	0.2542	-1.2236	0	-0.0021	19.4942	-0.8181
Season 2	0.3628	1.7869	10	0.0044	10.7135	2.5375
Season 3	0.099	2.2799	5	0.0083	21.4659	3.8485
Yearly	0.301	1.3527	0	0.0024	14.8805	1.1209

3.3 Minimum temperature

The trend was analyzed for a period of (1901–2002). In season 1 for Almora (**Table 27**) it can be observed that there was no significant trend in rainfall. The sen slope for monsoon season was -0.0013 while the relative change was found to be -

0.76. In season 2 there was increasing trend was found the sen slope was 0.0054 and relative change was 8.63. In season 3 there was increasing trend found the sen slope was 0.0048 and relative change was 4.84 in yearly there was no significant trend was found the sen slope was 0.002 and relative change was 1.81.

The trend was analyzed for a period of (1901–2002). In season 1 for Bageshwar (**Table 28**) it can be observed that there was no significant trend in rainfall. The sen slope for monsoon season was -0.0016 while the relative change was found to be -0.76. In season 2 there was no significant trend was found the sen slope was -0.0016 and relative change was 4.85. In season 3 there was increasing trend found the sen slope was 0.0065 and relative change was 4.84 in yearly there was no significant trend was found the sen slope was 0.0021 and relative change was 1.52.

The trend was analyzed for a period of (1901–2002). In season 1 for Chamoli (**Table 29**) it can be observed that there was no significant trend in rainfall. The sen slope for monsoon season was -0.0013 while the relative change was found to be -0.76. In season 2 there was increasing trend was found the sen slope was 0.0054 and relative change was 8.63. In season 3 there was no significant trend found the sen slope was 0.0084 and relative change was 4.84 in yearly there was no significant trend was found the sen slope was 0.002 and relative change was 1.81.

Table 27. Serial correlation analysis and trend analysis for minimum temperature for Almora District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	1.1209	-1.2999	0	-0.0013	11.2492	-0.7638
Season 2	0.4073	1.7576	10	0.0054	3.4453	8.6325
Season 3	0.1299	1.8163	10	0.0048	8.3498	4.8429
Yearly	0.4367	0.7247	0	0.002	5.6039	1.8134

Table 28. Serial correlation analysis and trend analysis for minimum temperature for Bageshwar District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	0.3674	-1.0006	0	-0.0016	13.4094	-0.7657
Season 2	0.264	1.4642	0	-0.0016	5.76	4.8558
Season 3	0.1431	1.96	10	0.0065	13.2449	4.8426
Yearly	0.4447	1.1825	0	0.0021	7.6289	1.5205

Table 29. Serial correlation analysis and trend analysis for minimum temperature for Chamoli District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	0.3569	-0.9125	0	-0.0013	11.2492	-0.7638
Season 2	0.3985	1.963	10	0.0054	3.4453	8.6325
Season 3	0.1555	1.5287	0	0.0048	8.3498	4.8429
Yearly	0.4947	1.159	0	0.002	5.6039	1.8134

The trend was analyzed for a period of (1901–2002). in season 1 for Champawat (**Table 30**) it can be observed that there was no significant trend in rainfall. The sen slope for monsoon season was -0.002 while the relative change was found to be-0.78. In season 2 there was increasing trend was found the sen slope was 0.0047 and relative change was 3.98. In season 3 there was increasing trend found the sen slope was 0.006 and relative change was 3.51 in yearly there was no significant trend was found the sen slope was 0.0017 and relative change was 0.97.

The trend was analyzed for a period of (1901–2002). In season 1 for Dehradun (**Table 31**) it can be observed that there was decreasing trend in rainfall. The sen slope for mon-soon season was -0.0036 while the relative change was found to be -1.47. In season 2 there was increasing trend was found the sen slope was 0.0037 and relative change was 3.56 in season 3 there was increasing trend found the sen slope was 0.0077 and relative change was 8.89 in yearly there was no significant trend was found the sen slope was 0.0016 and relative change was 0.94.

The trend was analyzed for a period of (1901–2002). In season 1 for Garwal (**Table 32**) it can be observed that there was decreasing trend in

rainfall. The sen slope for monsoon season was -0.0026 while the relative change was found to be -1.053. In season 2 there was increasing trend was found the sen slope was 0.004 and relative change was 3.73 in season 3 there was increasing trend found the sen slope was 0.0063 and relative change was 3.98 in yearly there was no significant trend was found the sen slope was 0.0013 and relative change was 0.75.

Table 30. Serial correlation analysis and trend analysis for minimum temperature for Champawat District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	0.3335	-1.1414	0	-0.002	16.8885	-0.7819
Season 2	0.3957	1.9043	10	0.0047	6.8631	3.9885
Season 3	0.1261	1.7957	10	0.006	16.915	3.5128
Yearly	0.4185	1.0651	0	0.0017	10.4251	0.9711

Table 31. Serial correlation analysis and trend analysis for minimum temperature for Dehradun District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	0.2082	-2.1332	-5	-0.0036	19.7902	-1.4755
Season 2	0.3263	1.6813	10	0.0037	6.724	3.5687
Season 3	0.1364	2.3268	1	0.0077	15.501	4.8975
Yearly	0.3399	0.9125	0	0.0016	11.1407	0.9486

Table 32. Serial correlation analysis and trend analysis for minimum temperature for Garhwal District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	0.2759	-1.7576	-10	-0.0026	17.8706	-1.053
Season 2	0.3929	1.7693	10	0.004	6.2136	3.7351
Season 3	0.1262	1.9865	5	0.0063	15.8154	3.9833
Yearly	0.3831	0.7394	0	0.0013	10.4616	0.7524

The trend was analyzed for a period of (1901–2002). In season 1 for Hardwar (**Table 33**) it can be observed that there was decreasing trend in rainfall. The sen slope for monsoon season was -0.0055 while the relative change was found to be -2.20. In season 2 there was increasing trend was found the sen slope was 0.0038 and relative change was 3.51, in season 3 there was increasing trend found the sen slope was 0.0076 and relative change was 4.63 in yearly there was no significant trend was found the sen slope was 0.0016 and relative change was 0.91.

The trend was analyzed for a period of (1901–2002). In season 1 for Nainital (**Table 34**) it can be observed that there was no significant trend in rainfall. The sen slope for monsoon season was -0.0025 while the relative change was found to be -1.01. In season 2 there was increasing trend was found the sen slope was 0.004 and relative change was 3.76. In season 3 there was no significant trend found the sen slope was 0.0053 and relative change was 3.01 in yearly there was no significant trend was found the sen slope was 0.0013 and relative change was 0.71.

The trend was analyzed for a period of (1901–2002). In season 1 for Pithodagar (**Table 35**) it can be observed that there was nosignificant trend in rainfall. The sen slope for monsoon season was -0.0008 while the relative change was found to be -0.48. In season 2 there was increasing trend was found the sen slope was 0.0058 and relative change was 9.85. In season 3 there was no significant trend found the sen slope was 0.0052 and relative change was 5.36 in yearly there was no significant trend was found the sen slope was 0.0022 and relative change was 2.044.

Table 33. Serial correlation analysis and trend analysis for minimum temperature for Haridwar District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	0.1487	-3.0662	-1	-0.0055	25.5878	-2.2058
Season 2	0.3479	1.7517	10	0.0038	6.8057	3.5119
Season 3	0.1214	2.3034	5	0.0076	16.2155	4.6353
Yearly	0.2852	1.0534	0	0.0016	12.4939	0.9109

Table 34. Serial correlation analysis and trend analysis for minimum temperature for Nainital District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	0.2954	-1.6167	0	-0.0025	17.9395	-1.0119
Season 2	0.4123	1.8221	10	0.0044	6.514	3.7608
Season 3	0.0966	1.5258	0	0.0053	17.5028	3.0192
Yearly	0.4111	0.6837	0	0.0013	10.5588	0.7121

Table 35. Serial correlation analysis and trend analysis for minimum temperature for Pithodagar District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	0.3825	-0.4431	0	-0.0008	10.7559	-0.4804
Season 2	0.386	2.0921	5	0.0058	3.3051	9.8564
Season 3	0.1541	1.6402	0	0.0052	8.0658	5.3635
Yearly	0.479	1.3057	0	0.0022	5.6357	2.0442

The trend was analyzed for a period of (1901–2002). In season 1 for Rudraprayag (**Table 36**) it can be observed that there was no significant trend in rainfall. The sen slope for monsoon season was -0.0016 while the relative change was found to be -0.91. In season 2 there was increasing trend was found the sen slope was 0.005 and relative change was 7.28. In season 3 there was increasing trend found the sen slope was 0.0069 and relative change was 6.50 in yearly there was no significant trend was found the sen slope was 0.0025 and relative change was 2.14.

The trend was analyzed for a period of (1901–2002). In season 1 for Tiharigarwal (**Table 37**) it can be observed that there was no significant trend in rainfall. The sen slope for monsoon season was -0.0024 while the relative change was found to be -1.05. In season 2 there was increasing trend was found the sen slope was 0.004 and relative change was 4.18. In season 3 there was increasing trend found the sen slope was 0.0069 and relative change was 4.75 in yearly there was no significant trend was found the sen slope was 0.0014 and relative change was 0.91.

Table 36. Serial correlation analysis and trend analysis for minimum temperature for Rudraprayag District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	0.2993	-1.0416	0	-0.0016	12.6194	-0.9128
Season 2	0.3859	1.9982	5	0.005	3.896	7.2844
Season 3	0.1488	2.3855	1	0.0069	10.4692	6.5006
Yearly	0.4122	1.3233	0	0.0025	6.6802	2.1487

Table 37. Serial correlation analysis and trend analysis for minimum temperature for Tiharigarwal District

Season	r_1	ZMK	Trend	Sen slope	Intercept	Relative change
Season 1	0.2516	-1.4466	0	-0.0024	17.3722	-1.055
Season 2	0.3615	1.6754	10	0.004	5.9132	4.1847
Season 3	0.1382	2.1508	5	0.0069	14.3856	4.7506
Yearly	0.1382	0.8539	0	0.0014	9.4437	0.9131

The trend was analyzed for a period of (1901–2002). in season1 for Utham Singh Nager (**Table 38**) it can be observed that there was decreasing trend in rainfall. The sen slope for monsoon season was -0.0032 while the relative change was found to be -1.26. In season 2 there was increasing trend was found the sen slope was 0.0045 and relative change was 3.91. In season 3 there was increasing trend found the sen slope was 0.006 and relative change was 3.49 in yearly there was no significant trend was found the sen slope was 0.0015 and relative change was 0.81.

The trend was analyzed for a period of (1901–2002). In season 1 for Uttarkashi (**Table 39**) it can be observed that there was no significant trend in rainfall. The sen slope for monsoon season was -0.0016 while the relative change was found to be -0.94. In season 2 there was increasing trend was found the sen slope was 0.0046 and relative change was 7.94. In season 3 there was increasing trend found the sen slope was 0.0054 and relative change was 5.61 in yearly there was no significant

trend was found the sen slope was 0.0022 and relative change was 2.01.

Table 38. Serial correlation analysis and trend analysis for minimum temperature for Udhamsingh Nager

Season	r_1	ZMK	Trend	Sen slope	Intercept	relative change
Season 1	0.2545	-1.963	-10	-0.0032	19.1573	-1.263
Season 2	0.4097	2.051	5	0.0045	6.5669	3.9117
Season 3	0.12	1.8574	10	0.006	17.0131	3.4959
Yearly	0.3883	0.801	0	0.0015	11.0223	0.8199

Table 39. Serial correlation analysis and trend analysis for minimum temperature for Uttarkashi District

Season	r_1	ZMK	Trend	Sen slope	Intercept	relative change
Season 1	0.3022	-0.9419	0	-0.0016	12.2031	-0.9433
Season 2	0.358	1.828	10	0.0046	3.4203	7.9417
Season 3	0.157	1.6872	10	0.0054	7.9486	5.6152
Yearly	0.456	1.2999	0	0.0022	5.8631	2.0111

4. Conclusions

In this study, trend analyses of rainfall, maximum temperature and minimum temperature were carried out for the Uttarakhand state. The study inferred that in Season I (monsoon season) seven out of thirteen districts have exhibited a declining trend in rainfall. In Season II (winter season) no significant trend was found. An increasing trend was observed in rainfall in Season III (summer season) for Haridwar and Uddham Singh Nagar districts. The yearly analysis of rainfall exhibited a decreasing trend in five districts of Uttarakhand. A decreasing trend was observed in Season I for maximum temperature in five districts of Uttrakhand state. An increasing trend of maximum temperature was exhibited by eight districts in winter season. In summer season, the entire state (except for Uddham Singh Nagar district) showed an increasing trend for maximum temperature. However, the yearly analysis did not show any trend for maximum temperature. For minimum temperature, in season I, a decreasing trend was observed for four districts. An increasing trend was observed in eight districts in season II. Except for Bageshwar district, entire state has exhibited an increasing trend of minimum temperature in Season III. However, the yearly analysis did not exhibit any trend for minimum temperature.

Conflict of interest

The authors declared no conflict of interest.

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