Original Research Article

SPATIAL AND TEMPORAL TREND ANALYSIS OF PRECIPITATION AND TEMPERATURE DATA IN MALWA REGION OF KSHIPRA RIVER BASIN, INDIA

Abstract

This study investigates the trends of two climatic variables viz. rainfall and temperature (mean, minimum, maximum) for annual and seasonal (pre-monsoon, monsoon, post-monsoon, winter) basis at four station namely Mahidpur, Alot, Dewas, Indore in Kshipra river basin, India. The non-parametric test like Mann- Kendell test and Sen's slope estimator was applied to analyse the trend of rainfall and temperature data series for the period of 1980 to 2012.The temperature data series analysis indicates statistically significant positive trend of maximum, minimum and average temperature in the annual and winter seasonal scale for all the four station.However, the trend of average temperature in post monsoon season was also significant except Alot station.The magnitude of the annual trend for average temperature (T_{avg}) ranges between from 0.020 ^{o}C/year (Indore) to 0.024 ^{o}C/year (Mahidpur).On annual scale, a non-significant increasing trend in rainfall was observed at stations, Indore and Alot, whereas decreasing trend was observed at station, Mahidpur and Dewas. The investigation of 32 years (1980-2012) data series was showed the years 2000 and 1993 as the break point/change year for rainfall and temperature series, respectively.On average, annual minimum, maximum and average temperature was found to increase by 1.5 % over the period 1993 to 2012.

Keyword: trend, Mann-Kendell, Spatial, temperature, rainfall, Kshipra, basin, India

1. Introduction

The changing climatic conditions and warming of environment has major impact on the water resources and agricultural sectors, and overall economy of the nation. Due to intensification of hydrological cycle, drastic and oppressive change in hydrologic parameters (like precipitation, evaporation and streamflow) have occurred which influencessignificantlythe flow regimes. Among various hydrologicparameters which govern the hydrological processes, Sonali and Kumar (2013) observed that temperature has a significant and direct effect on nearly all such variables. Air temperature is generally recognised as a good indicator of the state of climate globally because of its ability to represent the energy exchange process over the earth's surface with reasonable accuracy (Vinnikov et al., 1990; Thapliyal and Kulshrestha, 1991). However, the high temperature change warms the climate which leads to intensification of hydrological cycle such as higher rates of evaporation and increase of liquid precipitation. Some studies on temperature variation on global scale (Jones et al., 1986; Folland and Parker, 1990) have established the fact that the earth's atmosphere has witnessed a significant warming in last century. The studies in mountainous areas like the Swiss and Polish Alps, the Rockies (Beniston et al., 1997; Wibig and Glowicki, 2002; Beniston, 2003; Diaz et al., 2003; Rebetez, 2004) and the Andes (Vuille et al., 2003) have demonstrated significant rise in air temperatures with alarming effects on their environment.

Several studies in India hadalso been carried out to determine the changes in temperature and rainfall along with its association with climate change. A study by Bhutiyani et al. (2007) in the north-western Himalaya region showed a significant rise in air temperature, with winter warming occurring at a faster rate. Dimri and Ganju (2007) foundthe increasing temperature and decreasing precipitationtrend at northern Himalaya region. Similarly Dash et al. (2007) also found an increase of 0.9 $^{\circ}$C in annual maximum temperature over the western Himalaya. In another study conducted by Duhan et al. (2013) demonstrated the variability and trends using annual and seasonal temperature variables for the 45 station in central India. They found a significant increase of 0.62°C/102 years in the annual minimum temperature, and 0.60°C/102 years in the annual maximum and mean temperature.

The changes in temperature, precipitation and other related climatic variables are likely to influence the amount and distribution of runoff in all river systems globally. The non-parametric methods such as Mann-Kendall trend test, Spearman's tau, Sen's slope, regression line, and Şen's innovative trend analysisare widely used for analysing the trends in a number of hydro-climatic time series namely rainfall, temperature, pan-evaporation, wind speed etc. (Hirsch et al., 1982; Yu et al. 1993; Kothyari and Singh, 1996; Fu et al., 2004; Tebakari et al., 2005; Jhajharia et al., 2009; Kumar et al., 2010; Chattopadhyay et al., 2011; Dinpashoh et al., 2011; Jain and Kumar, 2012; Jain et al., 2012b; Singh et al., 2014, Meena et.al., 2015). No detailed study of trends for climatic data, in particular temperature and precipitation for the

Malwa region of Kshipra river basin has been reported. Keeping in the view, the present study aims is to detect and quantify the trends of climatic variables such as precipitation and Temperature by using non-parametric statistical tools. The Mann-Kendall test and Sen's estimator of slope method (non-parametric) have been applied to determine the trend of temperature and rainfall series available for various meteorological stations distributed over the Kshipra river basin. The trends and their magnitude for these climatic variables have been determined for both annual as well as seasonal time scale.In addition, the shift analysis has also been performed using Pettitt's method.

2. Materials and Methods

2.1. Study Area

The study catchment Kshipra is located in the western part of Madhya Pradesh state, India. It falls in the semi-arid sub-tropical type climatic region of India (Fig. 1). Geographically, the Kshipra watershed is located between 75° 25ˈ 04ˈˈ to 76° 13ˈ 19ˈˈE longitude and 22° 27ˈ 29ˈˈ to 23° 56ˈ 40ˈˈ N latitude. It covers a geographical area of 5617 km^2 having elevation ranges from 444 m at the outlet and 819 m at the ridge line in upper reaches. The slope of the watershed is upto15%. Approximately 51% of the area is occupied by agriculture followed by fallow land, barren land and open forests. The built-up area can be found only at around Indore, Ujjian and Dewas cities. The soil of the watershed is classified as Clay (38.28%), Loam (31.72%), Sandy loam (0.07%) and Silt clay (29.85%) (NBSSLUP, Nagpur). The annual rainfall ranges between 581.94 mmand 1299.13 mm, and most (about 80%) of the rainfall is concentrated in the months July, August and September (or known as monsoon season in India). Daily mean temperature ranges from a maximum of 45.5 °C (May) to minimum of 6 °C (January). The water of the Kshipra River is being used for drinking, industrial and irrigation purposes. Apart from this, the river also has spiritual importance and treated as holy and sacred. Ujjain one of the ancient and shrine city is located on the bank of Kshipra River, where Maha-Kumbh Mela (Hindus big pilgrimage fair) organized once in every 12 years.

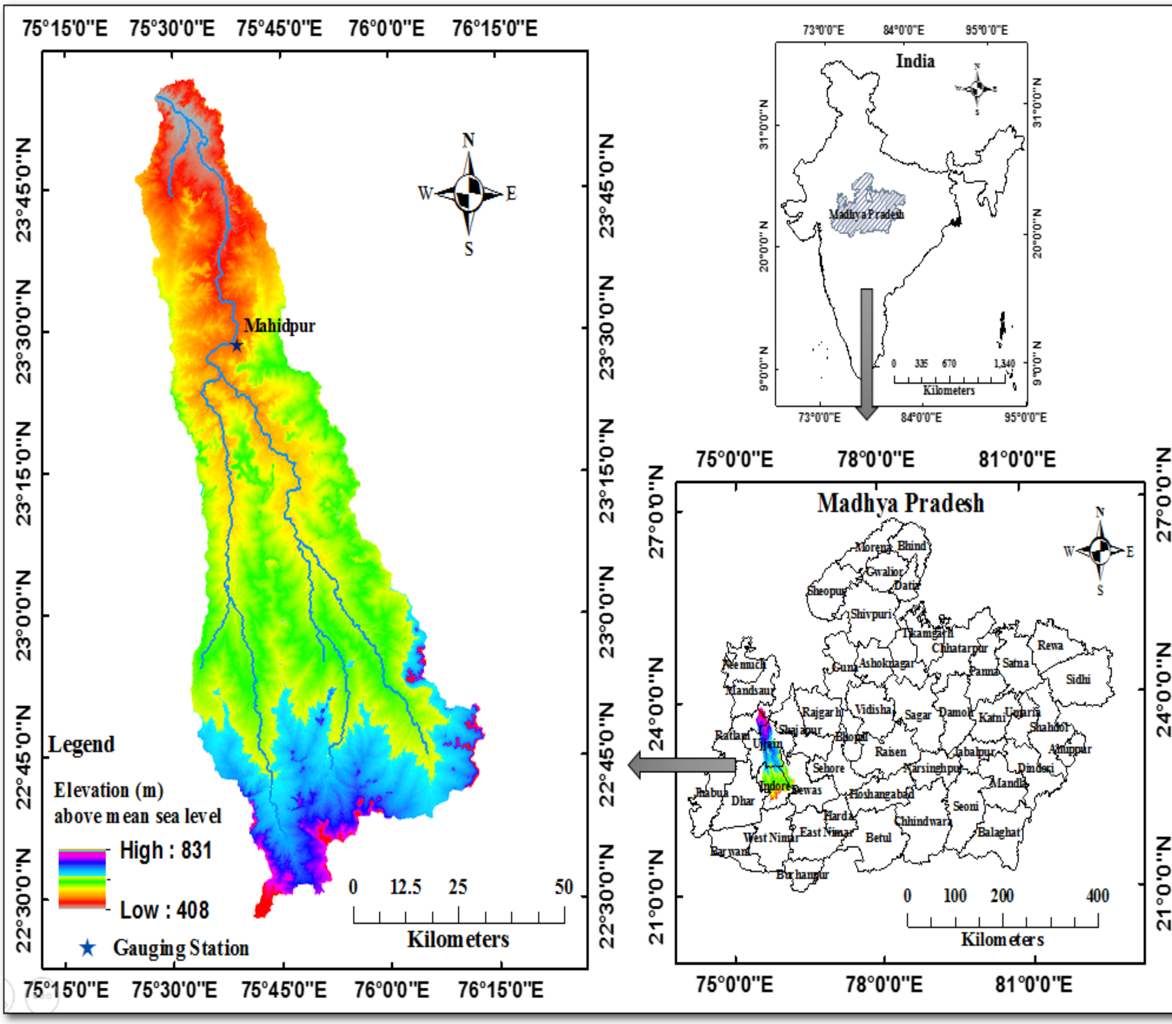

Fig. 1: Location map of Kshipra river basin.

2.2. Meteorological Data Used

The meteorological data such as temperature and rainfall for the stations Dewas, Indore, Mahidpur and Alot was collected from office of the State Data Centre situated at Bhopal, Madhya Pradesh, India. The detail of characteristics of each station is given in Table 1. A total of 32 years (1980-2012) of daily temperature (mean, maximum and minimum) and rainfall data have been used for the trend analysis.

Table 1. Details of the meteorological stations located in the study area.

SI. No.	Station	Latitude	Longitude	Altitude (m)
1	Dewas	22° 58' 45"	76° 04' 00"	535
2	Indore	22° 43' 00"	75° 54' 30"	563
3	Mahidpur	23° 28' 30"	75° 39' 20"	463
4	Alot	23°45' 55"	75° 33' 25"	450

2.3. Data Processing

The long term (1980-2012) data for the temperature and rainfall were compiled and processed for the seasonal and annual tends analyses. The available daily temperature data series has been used to compute the monthly time series as maximum (T_{max}), minimum (T_{min}), average (T_{avg}), for all the meteorological stations. The daily rainfall data series of four stations namely Dewas, Indore, Alot and Mahidpur were used to form monthly totals. To investigate the changes in climatic variables at different time scales, a year was divided into four principal seasons:Pre-monsoon season (March to May), Monsoon season (June to September), Post-monsoon season (October to November) and Winter season prevailing (December to February).

The monthly data of temperature and rainfall were further used to compute the annual and seasonal time series, which were in turn used for the investigation of trend on seasonal and annual time scale.

2.4. Methodology

In the present study, to analyze the trends of the climatic series of Temperature and Rainfall for each individual station, the popular statistical non-parametric methods such as Mann-Kendall test and Sen's estimator of slope method have been used. The two phase systematic approach has been adopted to determine the trend. Firstly, the Mann-Kendall test was used for the presence of a monotonic increasing or decreasing trend in the time series. Secondly, the Sen's estimator of slope test was used to determine the magnitude of the trend in the time series. The details of both the methods are described in the following sections.

2.4.1. Sen's Estimator of Slope

The magnitude of trend in a time series was determined using a non-parametric method known as Sen's estimator (Sen 1968). This method assumes a linear trend in the time series and has been widely used for determining the magnitude of trend in hydro-meteorological time series (Lettenmaier et al., 1994; Yue and Hashino, 2003; Partal and Kahya, 2006). In this method, the slopes (T_i) of all data pairs are first calculated as:

$$T_i = \frac{x_j - x_k}{j - k} \qquad \text{fori} = 1,2,\ldots,N \qquad (1)$$

Where$x_j$and x_k are 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:

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

A positive value of β indicates an upwards (or increasing) trend and a negative value indicates a downwards (or decreasing) trend in the time series.

2.4.2. Mann–Kendall Test

To ascertain the presence of a statistically significant trend in hydrologic climatic variables such as temperature and precipitation with reference to climate change, the non-parametric Mann–Kendall (MK) test has been employed by a number of researchers (Yu et al. 1993; Burn et al. 2004; Neeti and Eastman, 2011; Sayemuzzaman and Jha, 2014 ; Kisi and Ay, 2014). The MK method searches for a trend in a time series without specifying whether the trend is linear or non-linear. It checks the null hypothesis of no trend versus the alternative hypothesis of the existence of an increasing or decreasing trend. The statistic $S$for MK test is defined as:

$$S = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \text{sgn}(x_j - x_i) \quad (3)$$

Where, sgn is signam function; the x_j are the sequential data value, N is the number of data points. Assuming (x_j– x_i) = θ, the value of sgn(θ) is computed as follows:

$$\text{sgn}(\theta) = \begin{cases} 1 & if \quad \theta > 0, \\ 0 & if \quad \theta = 0, \\ -1 & if \quad \theta < 0. \end{cases} \quad (4)$$

This statistic represents the number of positive differences minus the number of negative differences for all the differences considered. For large samples, the test is conducted using a normal distribution (Helsel and Hirsch, 1992) with mean and variance as follows:

$$E[S] = 0 \quad (5)$$

$$Var(S) = \frac{N(N-1)(2N+5) - \sum_{k=1}^{n} t_k (t_k - 1)(2t_k + 5)}{18} \quad (6)$$

where,n is the number of tied (zero difference between compared values) groups and $t_k$is the number of data points in the k^{th} tied group. The standard normal deviate (Z-statistics) is then computed as (Hirsch et al.,1993):

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & if \quad S > 0 \\ 0 & if \quad S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & if \quad S < 0. \end{cases} \quad (7)$$

If the computed value of $|Z| > z_{\alpha/2}$, the null hypothesis H_0 is rejected at the α level of significance in a two-sided test. In this analysis, the null hypothesis was tested at 95% confidence level.

3. Results and Discussion

The Mann–Kendall (MK) test has been used for identification and testing the statistical significance of trend at confidence interval of 95%, prior to which data series of all the variables was checked for the presence of auto-correlation. The Sen's estimator of slope (SE) was then applied to estimate the magnitude of the trend over the study period.

3.1. Trends in Temperature

In order to analyze trend, the anomalies of maximum temperature (T_{max}), minimum temperature (T_{min}), average temperature (T_{avg}) were computed firstly; and then the MK test was applied for the data of each station at both seasonal and annual scale. The results of the test for the increasing or decreasing trend along with their magnitude which was estimated using Sen's slope estimator (SE) are given in Tables 2 to 4.

The results as presented inTable 2, shows an increasing trend in average temperature for all the four stations at annual as well as seasonal scale. The trend, however, was significant for annual and winter season scale. The magnitude of the annual trend for average temperature (T_{avg}) ranges from 0.020 ^{o}C/year (for Indore) to 0.024 ^{o}C/year (for Mahidpur). Similarly, magnitude of trend in the winter seasons was varies from 0.031 ^{o}C/year to 0.033^{o}C/year. In the post monsoon season the trend magnitude of average temperature was also significant except Alot station.Irrespective of scales (i.e. annual and seasonal), the average temperature for all the four station viz. Alot, Mahidpur, Indore and Dewas showed an increasing trend. For annual and winter temperature the rising trend is significant for all the four stations.

Table 2. Annual and Seasonal trend of average temperature (T_{avg})

Season	**Station**	**Z_{MK}**	**S**	**Sen slope(SE)**	**Serial correlation**	**Trend**
Annual	Alot	3.27	212	**0.023**	0.255	Rising
	Mahidpur	3.39	220	**0.024**	0.278	Rising
	Indore	3.21	208	**0.020**	0.269	Rising
	Dewas	3.55	230	**0.022**	0.253	Rising
Pre-monsoon (Mar-May)	Alot	1.01	66	0.015	0.133	Rising
	Mahidpur	1.13	74	0.016	0.164	Rising
	Indore	1.07	70	0.014	0.134	Rising
	Dewas	1.22	80	0.013	0.074	Rising
Monsoon (June- Sept.)	Alot	1.01	66	0.013	-0.039	Rising
	Mahidpur	1.07	70	0.013	-0.029	Rising
	Indore	0.70	46	0.009	-0.051	Rising
	Dewas	0.88	58	0.012	-0.056	Rising
Post-Monsoon (Oct-Nov.)	Alot	1.78	116	0.039	0.252	Rising
	Mahidpur	2.18	142	**0.042**	0.264	Rising
	Indore	2.22	144	**0.040**	0.251	Rising
	Dewas	2.43	158	**0.042**	0.265	Rising
Winter (Dec-Feb)	Alot	2.62	170	**0.032**	0.149	Rising
	Mahidpur	3.02	196	**0.033**	0.147	Rising
	Indore	3.08	200	**0.031**	0.158	Rising
	Dewas	3.08	200	**0.033**	0.169	Rising

(Bold shows the statistically significant trend at 5 % level)

As seen from Table 3, the trend for maximum temperature (T_{max}) is also similar to that for average temperature (T_{avg}); however, the magnitude of annual trend for maximum temperature (T_{avg}) ranges from 0.020 ^{o}C/year (for Indore) to 0.024^{o}C/year (for Mahidpur). Similarly, magnitude of trend in the winter seasons was varies from 0.033 ^{o}C/year to 0.036^{o}C/year.Statistically significant increasing trend is found in post-monsoon except Alot station. The Mahidpur and Dewas station also showed the highest slope values for Tmax (0.041^{o}C/year) for post- monsoon season.

Table 3. Annual and Seasonal trend of maximum temperature (T_{max})

Season	**Station**	**Z_{MK}**	**S**	**Sen**	**Serial**	**Trend**

Annual	Alot	3.15	204	**0.022**	0.248	Rising
	Mahidpur	3.36	218	**0.024**	0.266	Rising
	Indore	3.27	212	**0.020**	0.247	Rising
	Dewas	3.49	226	**0.021**	0.231	Rising
Pre-monsoon (Mar-May)	Alot	0.88	58	0.013	0.134	Rising
	Mahidpur	1.01	66	0.013	0.166	Rising
	Indore	0.85	56	0.012	0.150	Rising
	Dewas	1.01	66	0.011	0.099	Rising
Monsoon (June- Sept.)	Alot	0.95	62	0.014	-0.042	Rising
	Mahidpur	1.01	66	0.013	-0.030	Rising
	Indore	0.67	44	0.009	-0.054	Rising
	Dewas	0.95	62	0.010	-0.052	Rising
Post-Monsoon (Oct-Nov.)	Alot	1.87	122	0.039	0.231	Rising
	Mahidpur	2.22	144	**0.041**	0.236	Rising
	Indore	2.15	140	**0.039**	0.214	Rising
	Dewas	2.37	154	**0.041**	0.224	Rising
Winter (Dec-Feb)	Alot	2.62	170	**0.032**	0.167	Rising
	Mahidpur	3.11	202	**0.036**	0.170	Rising
	Indore	3.02	196	**0.034**	0.178	Rising
	Dewas	3.27	212	**0.036**	0.181	Rising

The trend for minimum temperature was also found to observe as increasing for all the four station for all time scales (Table 4). The trend however was significant for only annual and winter season scale. As seen from Table 4, the magnitude of annual as well as seasonal minimum temperature trend was relatively low as compared to maximum and average temperature. On average Mahidpur was the station who has observed highest rise in maximum/ minimum/ average temperature annually as well as seasonally.

Table 4 Annual and Seasonal trend of minimum temperature (T_{min})

Season	**Station**	**Z_{MK}**	**S**	**Sen**	**Serial**	**Trend**
Annual	Alot	2.43	158	**0.017**	0.077	Rising
	Mahidpur	3.42	222	**0.023**	0.106	Rising
	Indore	2.96	192	**0.020**	0.083	Rising
	Dewas	3.21	208	**0.021**	0.080	Rising
Pre-monsoon (Mar-May)	Alot	0.29	20	0.004	0.008	Rising
	Mahidpur	1.66	108	0.023	0.131	Rising
	Indore	1.44	94	0.019	0.083	Rising
	Dewas	1.5	98	0.017	0.035	Rising
Monsoon (June- Sept.)	Alot	1.38	90	0.015	-0.167	Rising
	Mahidpur	1.72	112	0.022	-0.075	Rising
	Indore	1.44	94	0.016	-0.115	Rising
	Dewas	1.6	104	0.019	-0.113	Rising
Post- Monsoon	Alot	1.87	122	0.033	0.038	Rising
	Mahidpur	1.81	118	0.033	0.019	Rising

(Oct-Nov.)	Indore	1.53	100	0.030	-0.014	Rising
	Dewas	1.78	116	0.035	-0.005	Rising
Winter (Dec-Feb)	Alot	2.06	134	**0.029**	0.041	Rising
	Mahidpur	2.34	152	**0.034**	0.021	Rising
	Indore	2.37	154	**0.029**	0.062	Rising
	Dewas	2.43	158	**0.031**	0.058	Rising

3.2. Trends in Rainfall

The general characteristics of seasonal and annual rainfall for all the four stations in the Kshipra river basin are given in Table 5. The coefficient of variation (CV) of the annual rainfall was varies from 20.2% (at Indore) to 27.4% (at Alot). It is evident from the Table 5 that all the station receives maximum rainfall during the monsoon season and least rainfall during the winter season. The contribution of monsoon rainfall varies from 91% (Indore) to 95% (Alot), while contribution of post-monsoon season almost 5%.

Table 5. Distribution of rainfall at different stations in Kshipra basin (1980-2012)

Station	**Annual**		**Pre-monsoon**		**Monsoon**		**Post-monsoon**		**Winter**	
	Mean	CV	Mean	% of	Mean	% of	Mean	% of	Mean	% of
Alot	882.1	27.4	8.3	0.9	837.6	95.0	31.2	3.5	5.0	0.6
Mahidpur	890.3	27.0	11.5	1.3	831.1	93.4	39.0	4.4	8.6	1.0
Indore	792.1	20.2	13.9	1.8	724.9	91.5	44.9	5.7	8.4	1.1
Dewas	868.6	22.2	11.6	1.3	806.2	92.8	39.0	4.5	11.8	1.4

Similar to temperature, the anomalies of rainfall and their trends were determined for all the stations considered in the study. The magnitude of the seasonal and annual trend in the time series as determined using the Sen's estimator is given in Table 6. The annual rainfall indicates decreasing trend at two station namely Mahidpur, Dewas; and increasing trends at other two stations with maximum increase (3.12 mm/year) at Indore. The increasing trend at Alot is of the order of 0.19 mm/year. Seasonal analysis of rainfall trends shows that all stations during post-monsoon and winter season experienced decreasing trend whereas pre-monsoon season indicated increasing trend except Dewasstation.

Table 6: Seasonal and annual trends in rainfall for different stations in Kshipra basin

Season	**Station**	**Z_{MK}**	**S**	**Sen slope (SE)**	**Serial correlation**	**Trend**
Annual	Alot	0.08	6	0.19	0.13	Rising
	Mahidpur	-0.26	-18	-1.51	-0.02	Falling
	Indore	0.98	64	3.12	0.14	Rising
	Dewas	-0.57	-38	-1.79	-0.13	Falling

Pre-monsoon (Mar - May)	Alot	0.73	48	0.13	0.09	Rising
	Mahidpur	**2.31**	150	**0.36**	0.26	Rising
	Indore	0.77	51	0.18	-0.09	Rising
	Dewas	-1.17	-73	-0.28	0.43	Falling
Monsoon (Jun - Sept)	Alot	0.20	14	0.77	0.16	Rising
	Mahidpur	-0.20	-14	-0.54	0.04	Falling
	Indore	1.29	84	4.14	0.18	Rising
	Dewas	-0.20	-14	-0.38	-0.10	Falling
Post-monsoon (Oct - Nov)	Alot	-1.49	-97	-0.53	0.11	Falling
	Mahidpur	-1.09	-71	-0.43	0.09	Falling
	Indore	-0.81	-53	-0.48	0.09	Falling
	Dewas	**-2.23**	-145	**-1.18**	0.09	Falling
Winter (Dec - Feb)	Alot	-1.67	-109	-0.10	0.00	Falling
	Mahidpur	-1.15	-75	-0.09	0.00	Falling
	Indore	**-1.98**	-129	**-0.14**	-0.06	Falling
	Dewas	**-4.26**	-274	**-0.64**	0.13	Falling

3.3. Homogeneity Test Analysis and Percentage Change of Rainfall and Temperature over a Period

Homogeneity test has been performed using long term data to find out the shift year, when a considerable change in the data series was observed. The shift year (break point) in the data series is calculated by Mann-Whitney-Pettit (MWP) test (Ngongondo, 2006; Goyal, 2014; Bližňák, et al., 2015) and results are given in Table 7. As seen from this table, overall the year 2000 and 1993 can be considered as the break point in case of rainfall and temperature series, respectively. The graphical representation of shift in theannual maximum and averagetemperature is given in Figs. 2 and 3, respectively.

Table 7. Value of Homogeneity test (Pettitt's test)

Station	**Rainfall**		**Tmax**		**Tmin**		**Tavg**	
	Pettitt's test		**Pettitt's test**		**Pettitt's test**		**Pettitt's test**	
	Shift year	**P value**	**Shift year**	**P value**	**Shift year**	**P value**	**Shift year**	**P value**
Dewas	2000	0.401	1991	0.002	1993	0.005	1991	0.001
Indore	2006	0.177	1993	0.003	1993	0.006	1993	0.003
Alot	1999	0.895	1991	0.003	1993	0.059	1991	0.002
Mahidpur	2000	0.580	1993	0.002	1993	0.003	1993	0.002

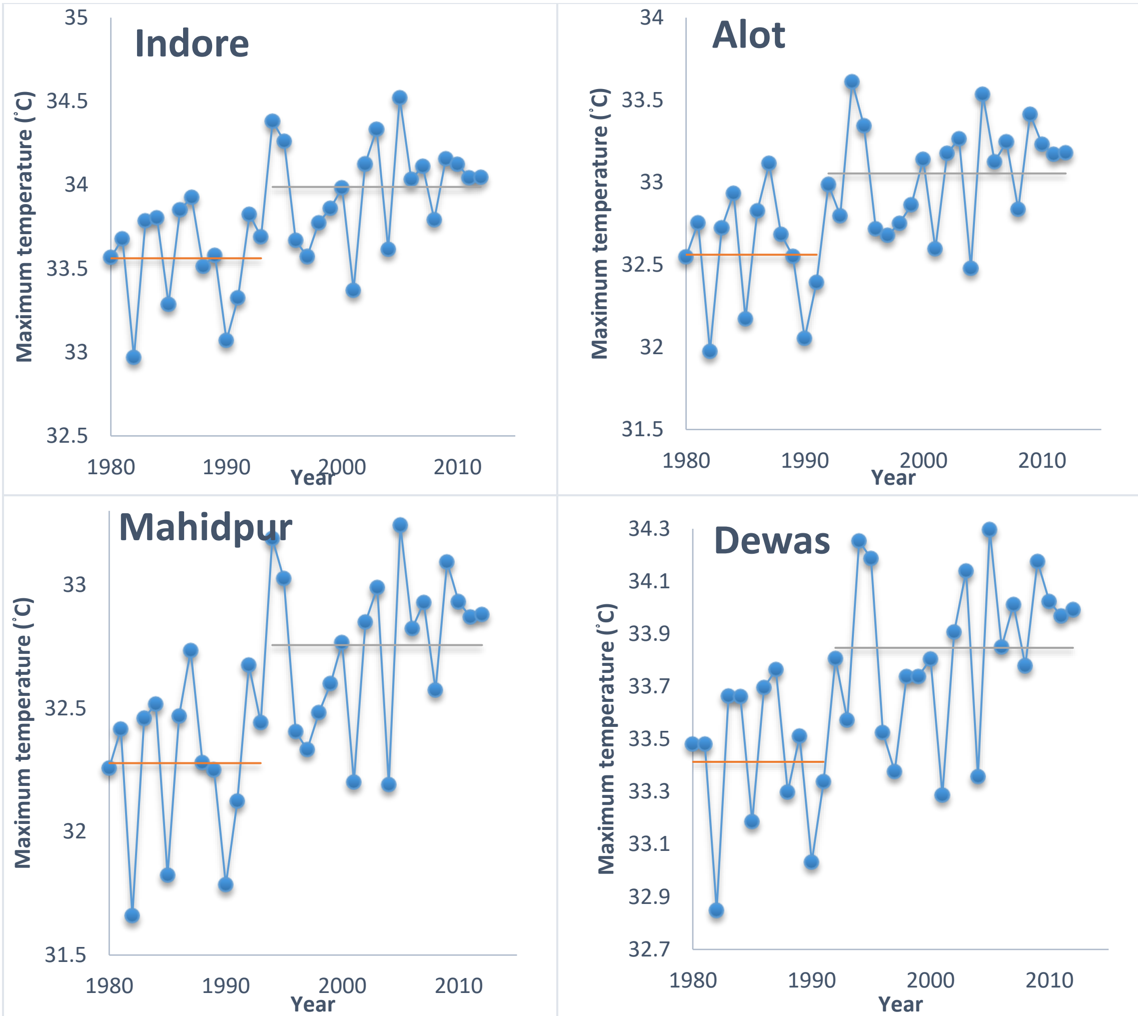

Fig. 2 Figure showing the shift change for average annual maximum temperature.

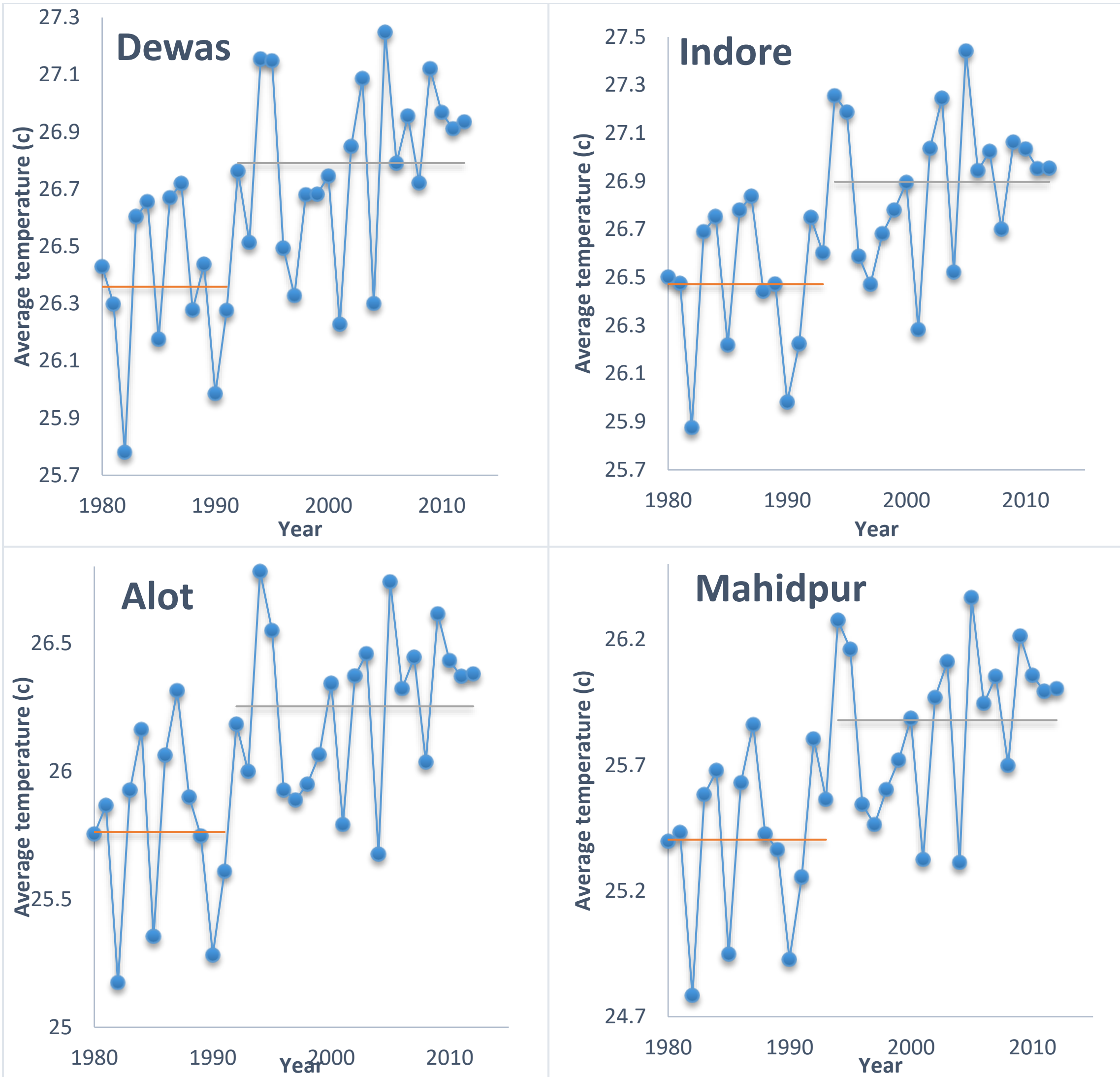

Fig.3 Figure showing the shift change for annual averge temperature.

3.4. Spatial analysis of rainfall and temperature data

The spatial interpolation technique (Singh and Chowdhury, 1986; Lebel et al., 1987) is employed to determine the spatial pattern of rainfall and temperature using ArcGIS 10.1. Here, the distribution of percentage change in annual and seasonal temperature as well as rainfall series was detected by considering shift year as base (or reference) year. Further, the distribution of these percentage change was interpolated by using the Inverse Distance Weighting (IDW) method to show their spatial distributions and results are given in Figs. 4 to 8. As seen from Fig.4, the highest seasonal average temperature change was observed in post monsoon season. In contract to it, the lowest change was seen to observe in monsoon season. Among all four stations, Mahidpur station was found to experience highest change in temperature in all the four seasons. Fig. 5 found to show the similar type of results as do the fig. 4. In case of seasonal minimum temperature change, the highest change was seen to observe in winter season followed by post monsoon, monsoon and pre-monsoon (Fig. 6). The Fig. 7 shows the seasonal distribution of rainfall change where the highest change was seen in winter season followed by pre-monsoon, post-monsoon and monsoon. Dewas station was found to observed highest negative change in winter season.

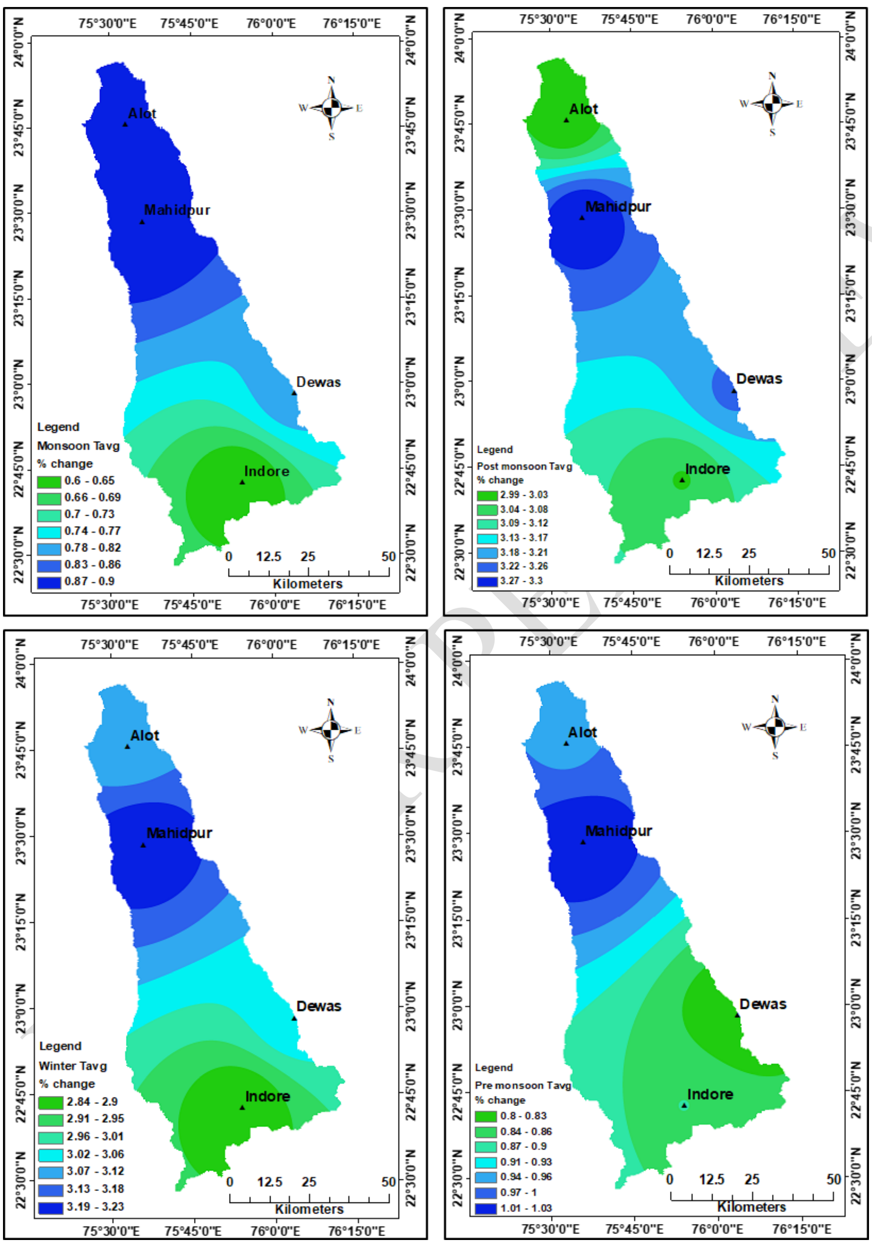

Fig.4 Figure showing the percentage change in seasonal average temperature over the period 1993-2012

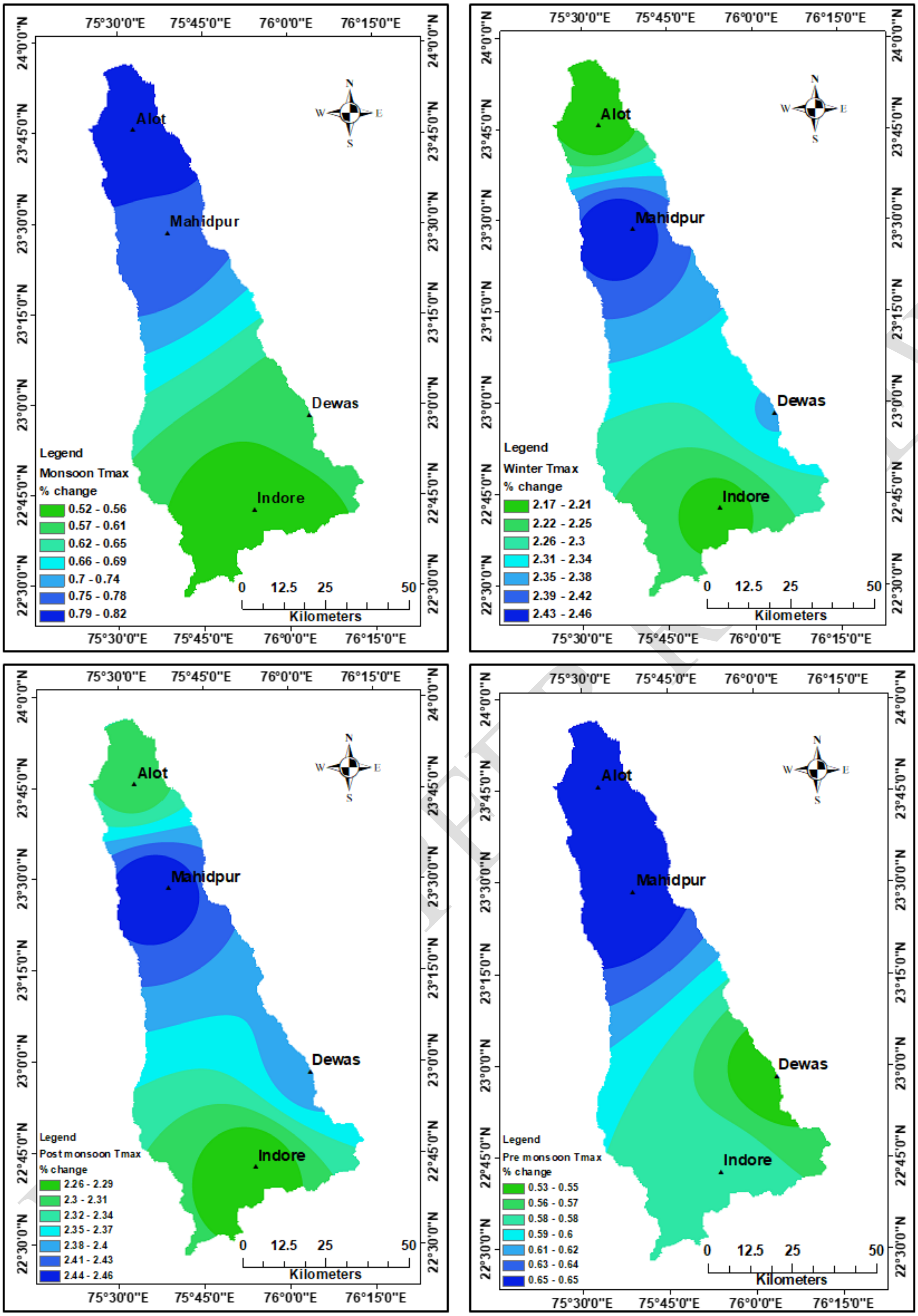

Fig.5 Figure showing the percentage change in seasonal maximum temperature over the period 1993-2012.

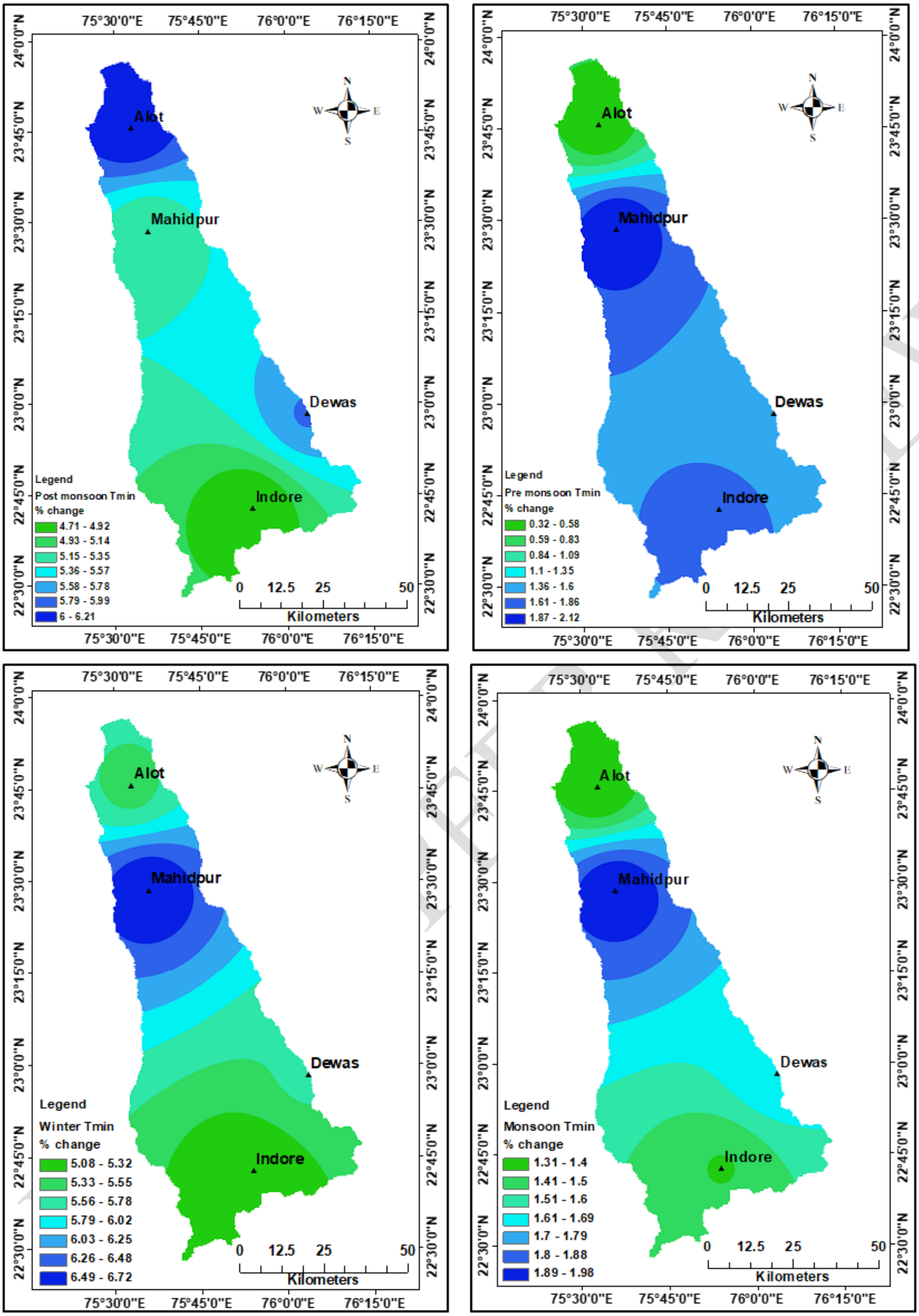

Fig.6 Figure showing the percentages change of seasonal minimum temperature for the period of 1993-2012.

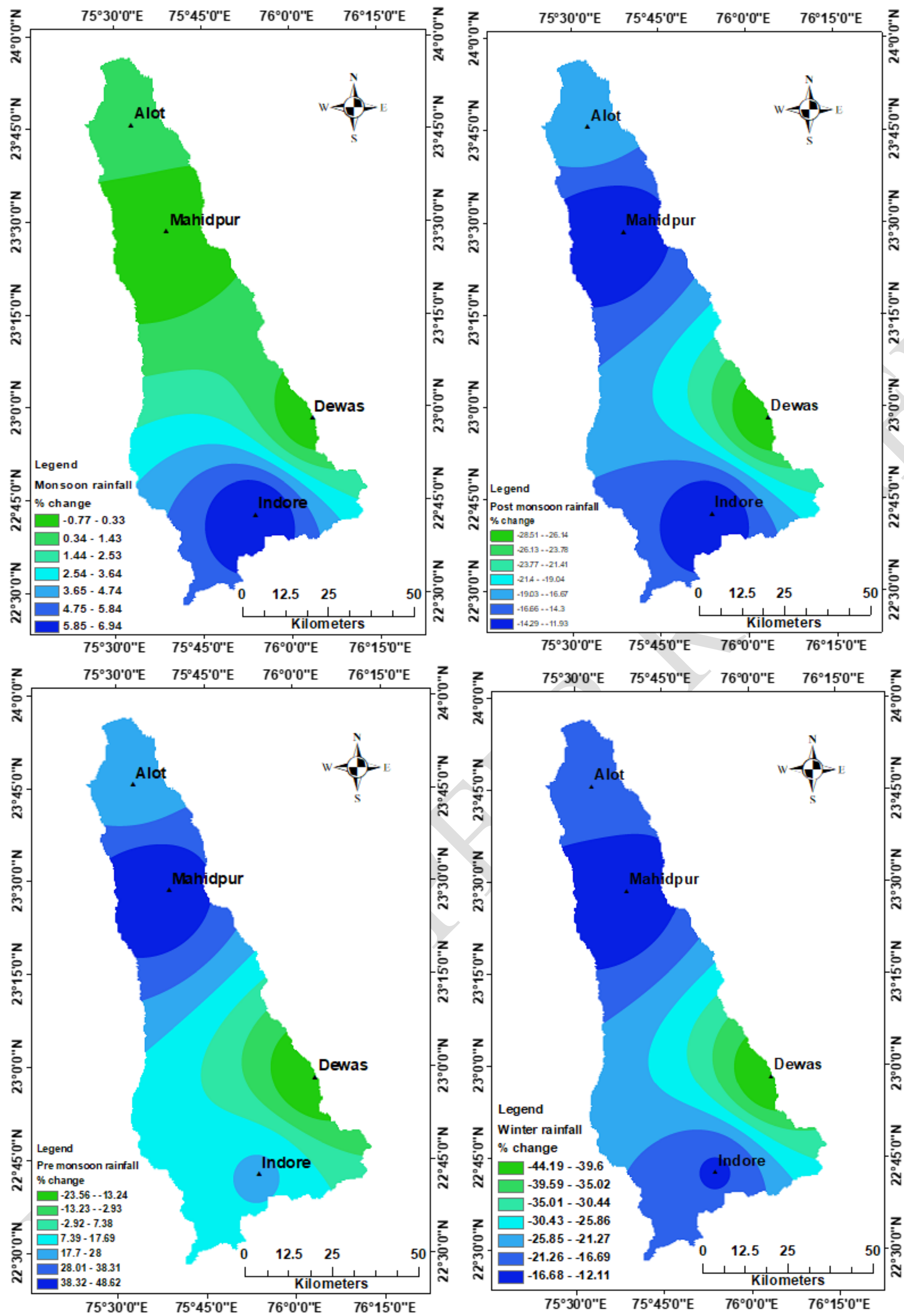

Fig. 7 Figure showing the Percentage change of seasonal rainfall for the period of 2000-2012.

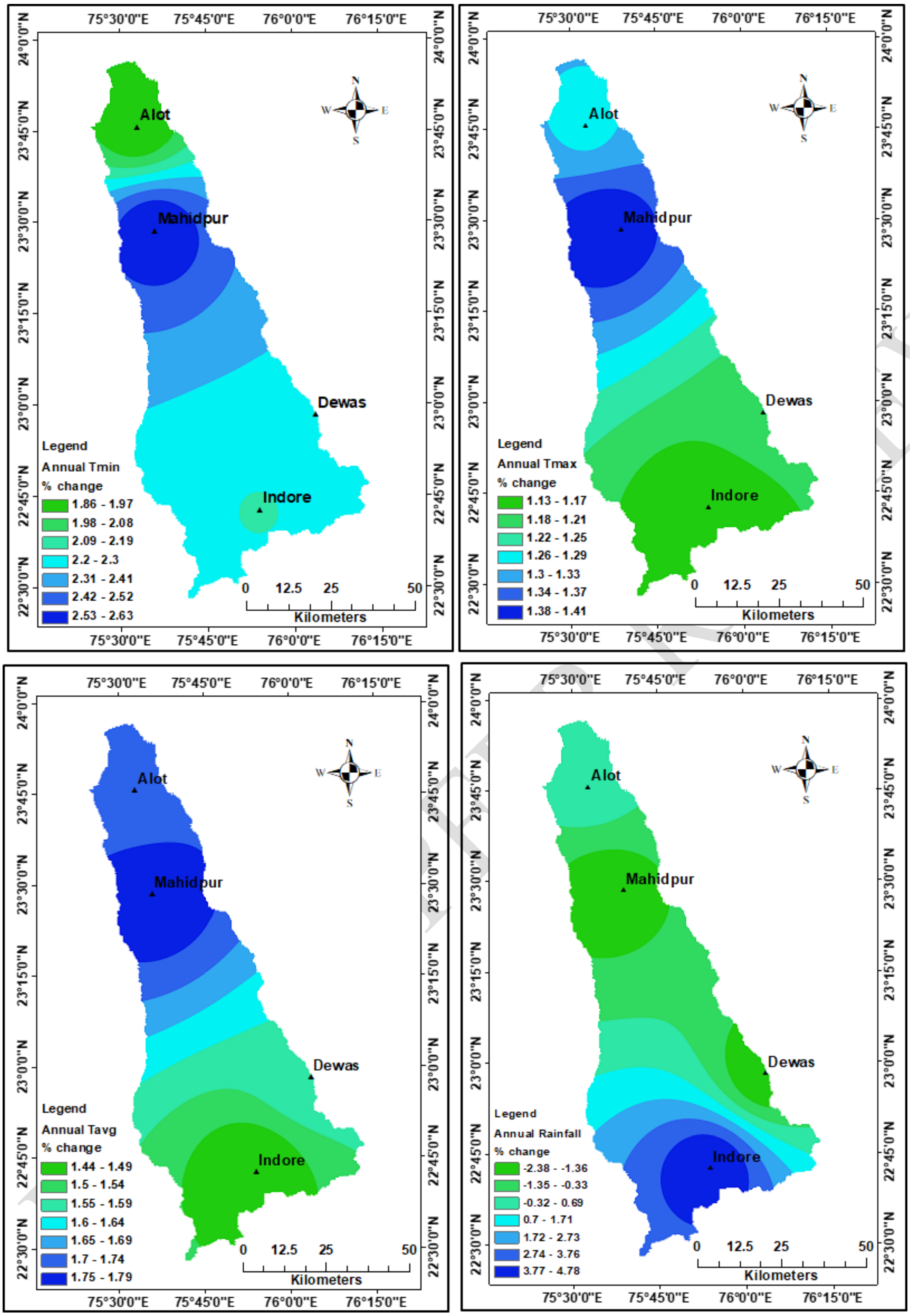

Fig.8 Figure showing the percentage change in rainfall and temperature on annual basis.

On annual basis, rainfall was deceased at Alot, Mahidpur and Dewas stations, whereas it was increased at Indore station. The annual temperature chance pattern was also same for all the four stations. On average, annual minimum, maximum and average temperature was found to increase by 1.5 % over the period 1993 to 2012.

4. Conclusions

The following conclusions can be drawn from the trendanalysis of 32 years series of rainfall and temperature (maximum, minimum and mean) data carriedout for annual as well as seasonal scale for Kshipra river basin, Madhya Pradesh, India.

1. An increase in annual and seasonal maximum, minimum and average temperature was observed at the all four stations.
2. Therise in trends of annual and winter temperature weresignificant for all the four stations.Among all four stations, Mahidpur station was found to experience highest change in temperature in all the four seasons.
3. The magnitude of rise inannual minimum and minimum temperatureswas varies from 0.017^{o}C/year to 0.023^{o}C and 0.020^{o}C/year to 0.024^{o}C/year, respectively.
4. On annual scale, a non-significant increasing trend in rainfall was observed at stations, Indore and Alot, whereas decreasing trend was observed at station, Mahidpur and Dewas. Moreover,the magnitude of the trend varies from −1.51 mm/year in Mahidpur to 3.12 mm/year in Indore.
5. The 32 years (1980-2012) data series of rainfall and temperature was analysed by means of Pettit's test, and the years2000 and 1993 were obtained as the break point/changeyear for rainfall and temperature series, respectively.
6. On average, annual minimum, maximum and average temperature was found to increase by 1.5 % over the period 1993 to 2012.

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