551.577.62 (540.27)

Comparison of recent rainfall trend in complex hilly terrain of sub-temperate region of Uttarakhand

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सार – पहाड़ी और पर्वतीय पारिस्थितिकी तंत्र में कृषि, मुख्यतः नमी प्रतिबल की सामान्य उपस्थिति से वर्षा सिंचित होती है। भारतीय हिमालय क्षेत्र (IHR) में अनियमित वर्षा और प्रतिकूल टोपोलॉजी के कारण, कृषि सम्बंधी सूखा एक प्रमुख चिंता का विषय बन गया है। यह एक प्राकृतिक आपदा है जो समय के साथ विकसित होती है और उसका प्रभाव आमतौर पर लंबे समय तक रहता है। वर्तमान अध्ययन में भारत के उत्तराखंड राज्य के मध्य-हिमालयी क्षेत्र में स्थित अल्मोड़ा वेधशाला और आईसीएआर-वीपीआरएएस, प्रायोगिक फार्म हवालबाग, अल्मोड़ा के मौसम संबंधी आंकड़ों का उपयोग करते हुए 56 वर्ष के दीर्घकालिक (1964-2019) तथा शहरीकरण के बाद या वर्तमान अवधि (1980-2019) की वार्षिक, मौसमी और मासिक कालिक प्रवृति और वर्षा पैटर्न को चिह्नित करने का प्रयास किया गया है। मैन-केंडल (α ≤ 0.05; α ≤ 0.10) परीक्षण, सेन स्लोप और वर्षा विसंगति सूचकांक (RAI) को क्रमशः प्रवृति का पता लगाने, वर्षा के परिमाण में परिवर्तन और वर्षा की कमी के वर्ष की पहचान करने के लिए नियोजित किया गया। हवालबाग के सम्बंध में, सांख्यिकीय रूप से महत्वपूर्ण (α ≤ 0.05) शहरीकरण के बाद (1980-2019) मॉनसून पूर्व ऋतु (-2.38 मिमी / वर्ष) और वार्षिक वर्षा (-7.23 मिमी/वर्ष) के लिए कमी की प्रवृति पाई गई। जबकि शीत ऋतु में मुख्यालय, अल्मोड़ा में सेन स्लोप (-2.00 मिमी/वर्ष) के साथ सांख्यिकीय रूप से महत्वपूर्ण कमी की प्रवृति पाई गई। मॉनसून ऋतु में 1964-2019 के दौरान कमी की प्रवृति (α ≤ 0.10 पर सांख्यिकीय रूप से महत्वपूर्ण) पाई गई। हालांकि, दोनों स्टेशनों ने मॉनसून पूर्व, मॉनसूनोत्तर, शीत ऋतु और वार्षिक वर्षा की कम होती प्रवृति दिखाई। परिणामों से पता चला कि पिछले 10 वर्षों में सूखा वर्ष की आरएआई विश्लेषण आवृत्ति बढ़ रही थी। अध्ययन के परिणाम वर्ष की विभिन्न ऋतुओं में वर्षा की परिवर्तिता और उपलब्धता को समझने में मदद करेंगे और वर्षा सिंचित पहाड़ियों के लिए प्रभावी जल प्रबंधन और कृषि पद्धतियों को अपनाने के लिए प्रेरित करेंगे। यह अध्ययन क्षेत्रीय, वैज्ञानिक और नीति निर्माताओं के लिए मध्य-हिमालयी क्षेत्र में जलवायु परिवर्तन के प्रतिकूल प्रभाव को कम करने के लिए उपयुक्त रणनीति तैयार करने हेतु भी उपयोगी होगा।

ABSTRACT. Agriculture in hill and mountain ecosystem is predominantly rainfed with common occurrence of moisture stress. Due to erratic rainfall and adverse topology in the Indian Himalaya Region (IHR), agricultural drought has become a prime concern. It is a natural disaster which evolves in time and their impacts generally last a long period of time. The present study attempts to characterize annual, seasonal and monthly temporal trend and rainfall pattern of 56 years long-term (1964-2019) and post-urbanization or recent (1980-2019) period using meteorological data of ICAR-VPKAS, Experimental Farm Hawalbagh, Almoraand Headquarter office, Almora observatory located in mid-Himalayan region of Uttarakhand state of India. Man-Kendall (α ≤ 0.05; α ≤ 0.10) test, Sen.'s slope and rainfall anomaly index (RAI) were employed for detecting trend, changes in magnitude of rainfall and identifying rainfall deficit year, respectively. The statistically significant (α ≤ 0.05) decreasing trend was found during post-urbanization (1980-2019) with Sen.'s slope for pre-monsoon season (-2.38 mm/year) and annual (-7.26 mm/year) for Hawalbagh, while cold winter season shows statistically significant deceasing trend with Sen.'s slope (-2.00 mm/year) at Headquarter office, Almora. The decreasing trend in monsoon season (statistically significant at α ≤ 0.10) was found during (1964-2019). However, both the station showed decreasing rainfall trend for pre-monsoon, post-monsoon, cold winter season and annual season. Results revealed that RAI analysis frequency of drought year was increasing in last 10 years. The results of study will help in understanding the variation and availability of rainfall in different seasons of the year and motivate to adopt effective water management and agricultural practices for rainfed hills. This study will also be useful for regional, scientific and policy makers for preparing appropriate strategies in order to mitigate adverse impact of climate change in mid-Himalayan region.

Key words – Himalayan region, Water management, Deficit, Climate change.

1.   Introduction

Analysis of long-term data is the first step for accurate assessment of water resources potential in any region. It plays pivotal role in the development of water resources and efficient water management (Basistha *et al.*, 2009; Srivastava *et al.*, 2017; Kumari and Srivastava, 2020). It has direct impact on human activities such as livestock management, agriculture and economics of the country. Floods are as a result of heavy rain whereas droughts are caused by deficit of rainfall, both leading to reduced crop yields. Due to complicated physiographic condition, there is non-uniform spatio-temporal distribution of rainfall that is characterized by high altitude (Palazzi *et al.*, 2013; Srivastava *et al.*, 2020b). The distribution of rainfall over India has changed after 1950s, but major changes have occurred after 1975, which are associated with rapid urbanization and industrialization. Long-term analysis of rainfall pattern provides an understanding of characteristics of local rainfall and aids researcher to sort out efficient water management strategies to combat the non-availability of irrigation water during dry spells. Various studies in context of rainfall variability and trends in extreme events were analysed across the globe (Kiely *et al.*, 1998; Partal and Kahya, 2006; Srivastava *et al.*, 2020a). Impact of climate change on variability of rainfall and extreme rainfall events in India have been studied by several researchers (Jain and Kumar, 2012; Pingale *et al.*, 2014; Srivastava *et al.*, 2017, 2018; Elbeltagi *et al.*, 2020). For example, Sharma *et al.* (2000) reported positive trend for Kosi basin in Nepal and Kumar *et al.* (2005) reported positive trend of Himachal Pradesh in India. The negative rainfall trends are reported by others, such as Singh and Sen Roy (2002) for Beas basin and Kumar and Jain (2010) for Qazigund and Kukarnag of Kashmir. Various researchers pointed location, height of mountain, nature of convection, altitudinal and slope wise variation of rainfall. Despite the various numbers of researches mentioned above, our understanding of how urban environment alters local climatology in Himalaya is yet to be adequately understood.

The novelty of this study lies in the particularly in mountain environments, rainfall can be extremely variable in space and time. For many hydrological applications such as modelling, extrapolation of point rainfall measurements is necessary. The large variability in altitude, slope and aspect may increase variability by means of processes such as rain shading and strong winds. Therefore this analysis of rainfall in this region can be one of the alternatives towards improving Earth systems models. Based on analysing monthly and seasonal data for different time scale long term 1964-2019, post urbanization 1980-2019 Hawalbagh and Almora, the

TABLE 1

Trends of urban growth in Uttarakhand (1901-2011)

Census Years	Total population	Urban population	Urban content (%)	Urban growth (%)
1901	19,79,866	1,54,424	7.8	-
1911	21,42,258	1,79,332	8.37	16.13
1921	21,15,984	1,91,660	9.06	6.87
1931	23,01,019	1,95,797	8.51	2.16
1941	26,14,540	2,70,503	10.35	38.15
1951	29,45,929	4,00,631	13.6	48
1961	36,10,938	4,95,995	13.74	23.8
1971	44,92,724	7,34,856	16.36	48.16
1981	57,25,972	11,49,136	20.07	**56.38**
1991	71,13,483	16,34,084	22.97	42.2
2001	84,79,562	21,70,245	25.59	32.81
2011	1,01,16,752	30,91,169	30.55	42.43

result showed that monthly rainfall trend are not related to seasonal rainfall trend. Therefore, in this study, we have taken long-term rainfall data of two observatory, Headquarter office (Almora) and experimental field (Hawalbagh) of ICAR-VPKAS.

The reason behind limited studies in IHR is lack of information available on long-term rainfall data particularly to higher altitudes (Singh *et al.*, 1995; Pant, 2003). In the addition to this study was taken to assess changing water availability over the study area. In order to observe the temporal trend in annual, seasonal and monthly rainfall pattern, the whole study period was divided into two periods namely, a long-term (1964-2019) and a recent or post-urbanization period (1981-2019). The post-urbanization or recent period was selected based on urban growth population rate of Uttarkhand and recommendation of several researcher, *i.e.*, Naidu *et al.* (2009) and Choudhary *et al.* (2018) who have used the period 1970 onwards as post-urbanization or recent climate to observe the impact of climate change on the rainfall over Indian region. It is important to mention that the urban population in Uttarakhand increased from 16.36% of the total in 1971 to 20.7% in 1981, 22.97% in 1991 and 25.59% in 2001 (Table 1). The State registered highest growth of urban population during 1971-1981 (56.38%), however, decadal urban population growth declined slightly during 1981-1991 (42.20%) and 1991-2001 (32.81%) (Tiwari *et al.*, 2018). Furthermore, they reported 40% reduction in annual rainfall during 1986-2009 addressing the reason to urbanization growth in Himalaya. In another study, Joshi *et al.*, 2013 reported the
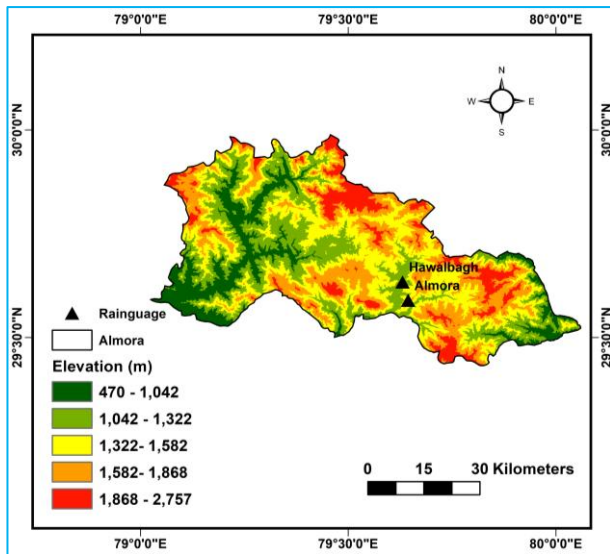
Fig. 1. Location of study area and rainguage

decline trend in rainy days for Almora, urban centre in central Himalaya. They also included the perception of local people regarding reduction in annual and monsoon rainfall. The post-urbanization era or recent climate (1980-2019) has been taken for analysing rainfall analysis as urbanization is attributed as the potential reason for altering the rainfall pattern (Datta, 2006; Sudhira and Gururaja, 2012). The rationale behind the study was no study has been made with most recent up-to-date and long-term station data (located in mid-Himalaya) to capture the impact of urbanization and climate change on seasonal, monthly and annual rainfall variability. Therefore, in the present study temporal characteristics of rainfall for mid Himalayan region of Uttarakhand state, India were analysed using long-term (1964-2019) monthly rainfall data with the following objectives (*i*) evaluate temporal trends and magnitude of annual, seasonal and monthly rainfall during long-term (1964-2019) and post-urbanization period (1980-2019) and (*ii*) computation of long-term rainfall anomaly index for identifying rainfall deficit year using long-term annual rainfall data.

2.   Study area and data used

The meteorological observatory for climate data recording was at the Experimental Farm, Hawalbagh (29°36' N; 79°40' E at 1250 m above sea level) and Headquarter office, Almora (29°35' N; 79°39' E at 1600 m above sea level) of the ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan (VPKAS, Almora, Uttarakhand (Fig. 1). The study area falls in the mid Himalayan range and exhibits a temperate climate. The digital elevation model of Almora district is shown in Fig. 1. The elevation of Almora district ranges from

470 m to 2757 m above mean sea level. The normal annual rainfall of the state is 1500 mm. The important crops harvested in the study area are finger millet, rice, black soyabean, barnyard millet, horse gram (Kharif) while, wheat, barley and lentil (Rabi). Finger millet, rice, wheat and lentil are the majors crops harvested in the study area. The entire area is influenced by the southwest monsoon, which arrives in the later parts of the June and continues till the end of the September. 70-80% of the total annual rainfall occurs during this period. Long-term rainfall data were used from the institute meteorological station located at Experimental farm, Hawalbagh, Almora (56 years, 1964-2019) and Headquarter office, Almora 39 years (1980-2019) with one year missing record of 1991. The whole year was divided into four seasons as per scheme followed by Basistha *et al.* (2009). The monthly time series of aerial rainfall was further used for preparing annual and seasonal, *i.e.*, monsoon season (JJAS), post-monsoon season (ON), cold winter season (DJF) and pre-monsoonal (MAM) rainfall time series.

3.   Methodology

3.1. *Mann-Kendall (MK) test*

The MK test (Mann, 1945; Kendall, 1948) computes statistics as:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \mathrm{sgn}\left(x_j - x_k\right)$$

where, S = normal distribution with the mean, n = number of observations (≥ 10) and x_j is the *j*th observation and sgn () is the sign function defined as sgn (α) = 1 if $\alpha>0$; sgn (α) = 0; if $\alpha = 0$ and sgn (α) = -1 if $\alpha<0$.
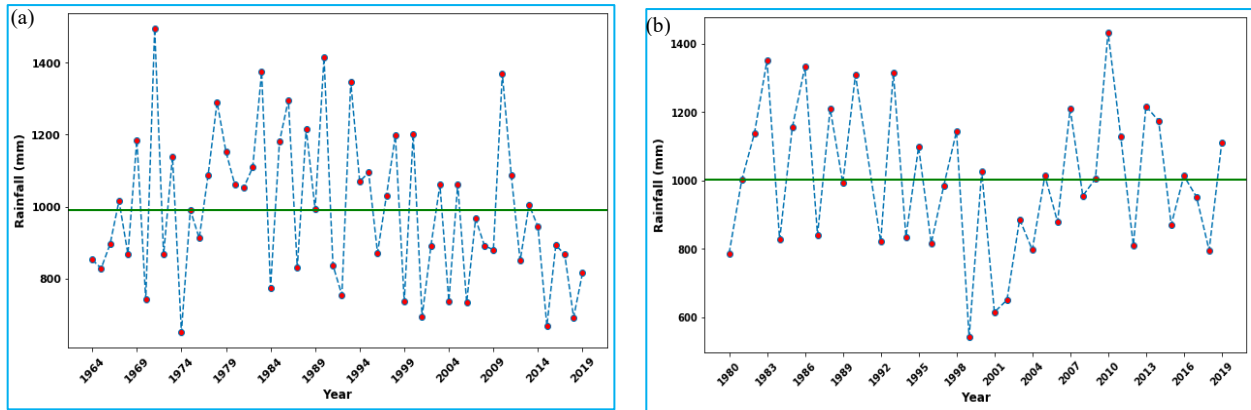
$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i-1)(2t_i+5)}{18}$$

where n = number of tied groups having similar value for a data group and t_i = number of data in the ith tied group. The actual MK statistics is given as follows:
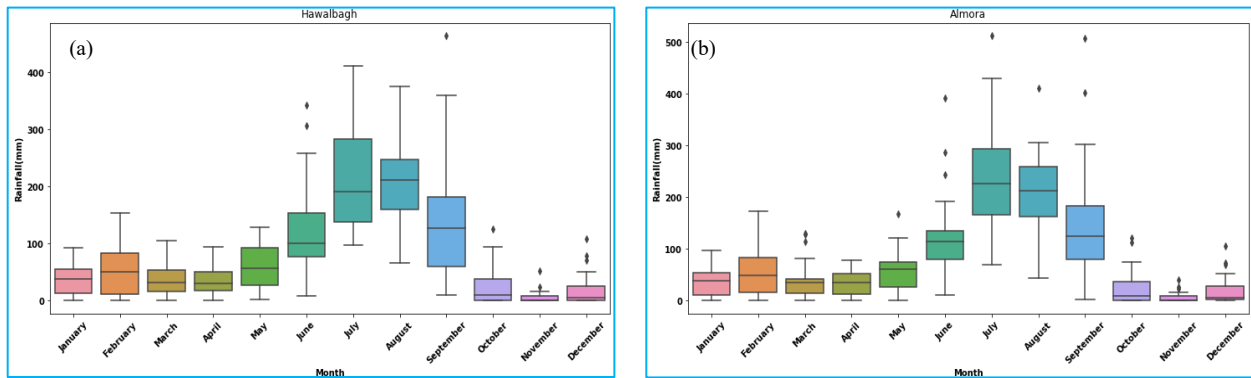
$$Z = \frac{S+1}{\sqrt{V(S)}}, \text{if } S < 0$$

$$Z = 0, \text{if } S = 0$$

$$Z = \frac{S+1}{\sqrt{V(S)}}, \text{if } S > 0$$

Figs. 2(a&b). An annual time series of rainfall (a) Hawalbagh (b) Almora

Fig. 3(a&b). Boxplot for monthly rainfall (a) 1964 to 2019 Hawalbagh (b) 1980-2019, Almora

Two hypotheses are made, *i.e.*, H_o (null hypothesis) and H_1 (alternative hypothesis). H_o indicates no statistically significant trend, while H_1 indicates a statistically significant trend.

3.2. *Sen.'s slope*

It is one of the most useful tests for analyzing atmospheric data and is a non-parametric. Computation of magnitude of change in a dataset is done by Sen.'s slope (Theil, 1950; Sen, 1968). This is a simple linear regression method, which can estimate the slope of the median of two different variables (dependent and independent). This is based on the assumptions of normality of residuals. It can be estimated using following equation:

$$d_{ijk} = \frac{X_{ij} - x_{ik}}{j - k}$$

where, X_{ij} and x_{ik} are data value, j and k are the time series.

3.3. *Linear regression*

For identifying the trend in the rainfall data, the statistical analysis of linear regression was used. Linear regression is one of the simplest methods to calculate the trend of data in the time series.

3.4. *Coefficient of variation*

The coefficient of variation (CV) is defined as standard deviation by mean. It was used in the study to reveal the inter-annual variation of annual average of rainfall.

3.5. *Rainfall anomaly index (RAI)*

It is simplest and effective index to measure rainfall deficit for a long-term data. Average monthly rainfall of ICAR-VPKAS, Experimental Farm, Hawalbagh for a period of 56 years (1964-2019) and rainfall anomaly of each year was collected using long-term monthly rainfall of study area. The years with low rainfall values indicates
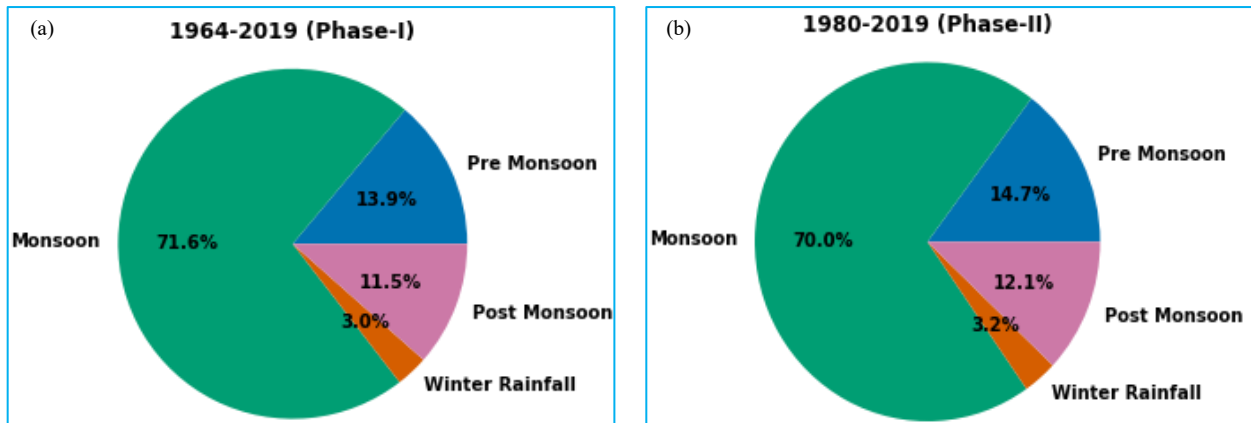
Figs. 4(a&b). Portion of seasonal variation of rainfall in Phase-I and Phase II of Hawlbagh
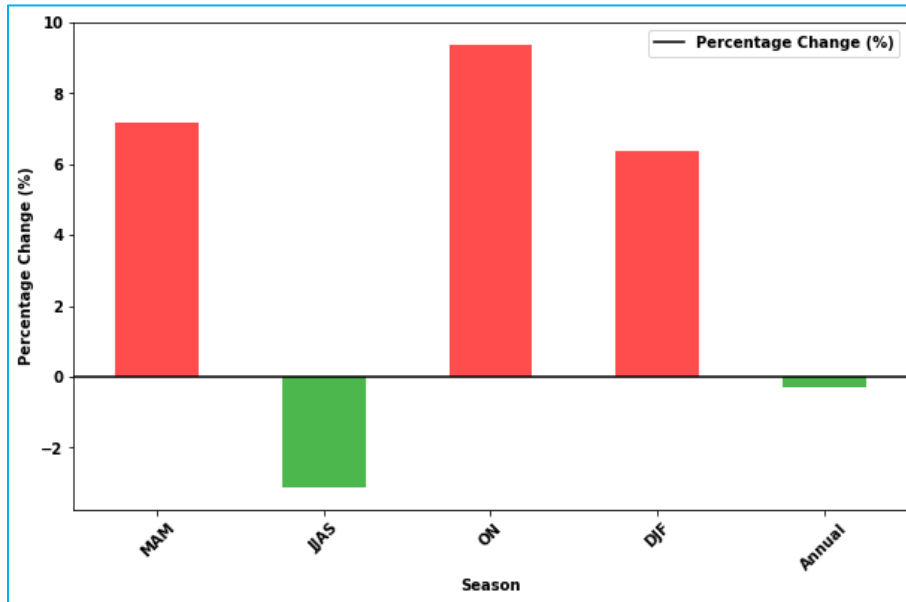

Fig. 5. Percentage change in mean seasonal rainfall (1981-2019) over (1964-2019) of Hawalbagh

negative. The following formula was used for calculation of Rainfall Anomaly Index (RAI):

$$RAI = \frac{(R-\mu)}{\sigma}$$

where, RAI = Rainfall Anomaly Index; R = Rainfall; μ = Long-term average annual rainfall; σ = Standard deviation.

4.   Results

4.1. Exploratory analysis of rainfall data

The mean annual rainfall of the area during the study period was 931.34 ± 208.42 mm with ~ 21% coefficient of variation. Data showed that the minimum and maximum ever recorded annual rainfalls were 650.8 mm (in 1974-the driest year) and 1496.0 mm (in 1971-the wettest year), respectively. The time series graph of annual rainfall at both observatories is presented in Figs. 2(a&b). The green line in the figure represents the mean annual rainfall for corresponding time series. During time span 1964 to 2019, 29 of 56 years showed rainfall less than the mean.

Seasonally, the maximum rainfall was recived during the monsoon season (JJAS), whereas the minimum rainfall was received during post-monsoon season (ON). The greatest variation was found for post-mosoon season rainfall (CV is 133%) it was observed that September month had the highest SD. The highest amount of monthly average rainfall was recorded in July (493.20 mm)

followed by August (210.47 mm) and June (133.39 mm). However, the lowest rainfall was recorded in the month of November (6.30 mm) followed by December (20.73 mm) and October (22.67 mm). Based on mean values and standard deviation, differences in rainfall distribution were observed between the analyzed months. Moreover, within each month, the monthly rainfall showed a distinct pattern for both the station [Figs. 3(a&b)].

4.2. Seasonal distributional of rainfall

4.2.1. Variation in seasonal rainfall

To understand the effect of post-urbanization era on seasonal variation we have analysed the seasonal variation in two phases, *viz.*, Phase-I: 1964-2019 (long-term) and Phase-II: 1980-2019 (post urbanization era). Results observed that the maximum amount of rainfall occurred during monsoon season in both the phases. It was found that there is a slight decrease in the portion of monsoon rainfall during post-urbanization period as compared to long-term period (1980-2019) [Figs. 4(a&b)].

4.2.2. Percentage change in seasonal rainfall

Fig. 5 revealed that the difference between averages rainfalls of two phases expressed as percentage of the first phase. The significant highest decrease (-3.12%) was observed in monsoon followed by annual rainfall (-0.27%) (Fig. 5). The slight decrease in annual rainfall was found might be due to recent cloud burst and high intense rainfall. The percentage change means seasonal rainfall received during post-urbanization period compared to long term rainfall in the study area.

4.2.3. Long-term (1964-2019) versus post-urbanization (1980-2019) trend

4.2.3.1. Monthly rainfall trend

Analysis of monthly rainfall temporal pattern provides a more detailed picture of rainfall trend and variability in the study area over study period. Data indicated that long-term 1964-2019 (56 years) and post-urbanization 1980-2019 (40 years) monthly rainfall trend analysis Monthly rainfall MK statistics indicates statistically significant increasing trend ($\alpha = 10\%$) for the month April with Sen.'s slope (0.38 mm/year) during long-term which is shown in bold font, while downward significant trend ($\alpha = 5\%$) was observed for March with Sen.'s slope (-2.02 mm/year) during post-urbanization era. January, May and December show significant decreasing trend ($\alpha = 10\%$) with Sen.'s slope -0.70 mm/year, -1.08 mm/year and -0.032 mm/year respectively. In case of Almora, January, February, March, May, June, October
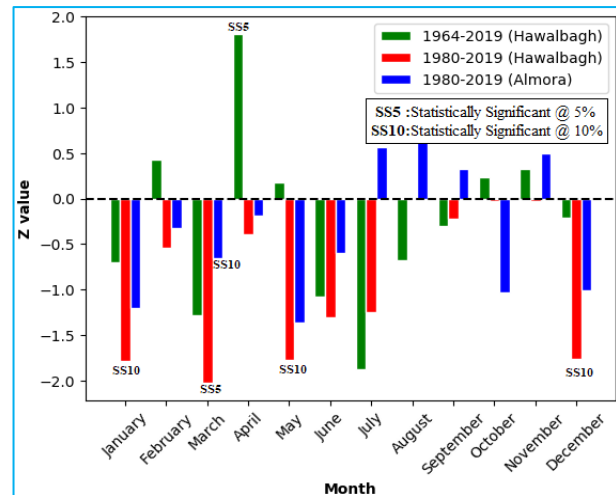

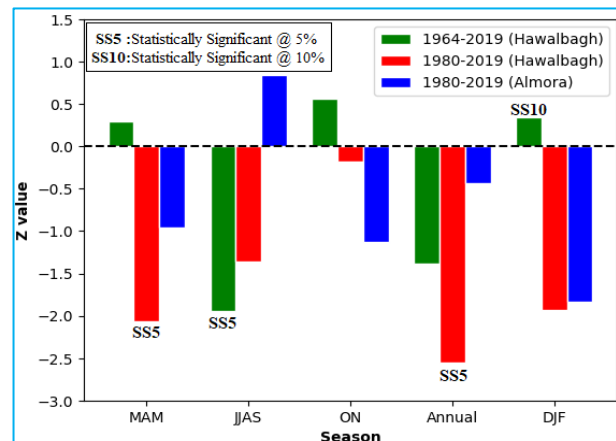**Fig. 6.** Overall trend analysis of monthly rainfall

**Fig. 7.** Overall trend analysis of annual and seasonal rainfall

and December shows decreasing trend out of which the trend of March is found to be significant at ($\alpha = 10\%$) with Sen.'s slope (-1.76 mm/year) shows similar trend to Hawalbagh (Fig. 6).

4.2.4. Annual and seasonal rainfall trend

Statistically significant declining monsoon rainfall trends were recorded in both long-term and post-urbanization era. Study area witnessed significant ($\alpha = 10\%$) rainfall decline trend in monsoon season during long-term (1964-2019) with Sens's slope (-2.82 mm/year). Interestingly, during post-period (1980-2019), overall trend in annual and pre-monsoon rainfall was found to be decreasing which is statistically significant ($\alpha = 5\%$). In case of Almora, pre-monsoon, post-monsoon, cold winter season as well as annual rainfall pattern showed decreasing trend out of which winter monsoon season showed significant decreasing trend at ($\alpha = 10\%$) (Fig. 7).
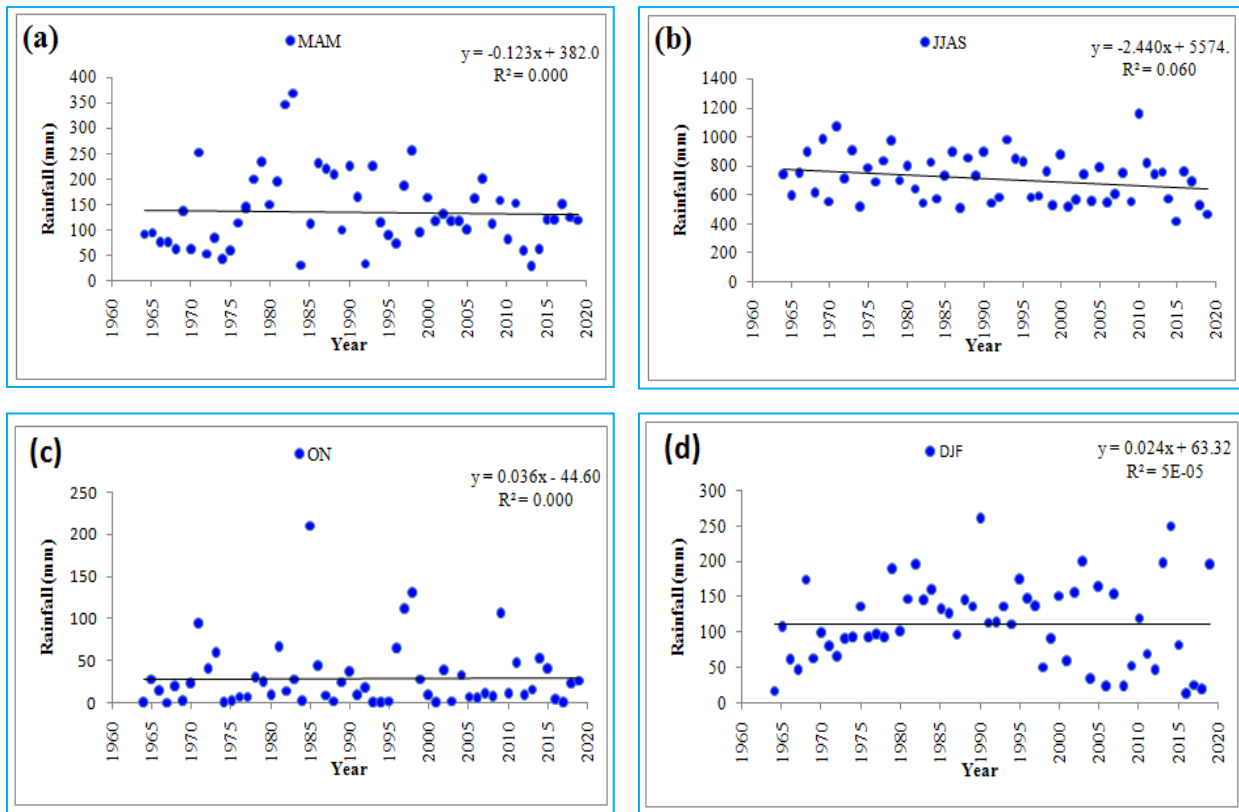
Figs. 8a(a-d). Linear regression trends of seasonal rainfall for 56 years (1964 to 2019), (a) March to May, (b) June to September, (c) October & November and (d) December to February
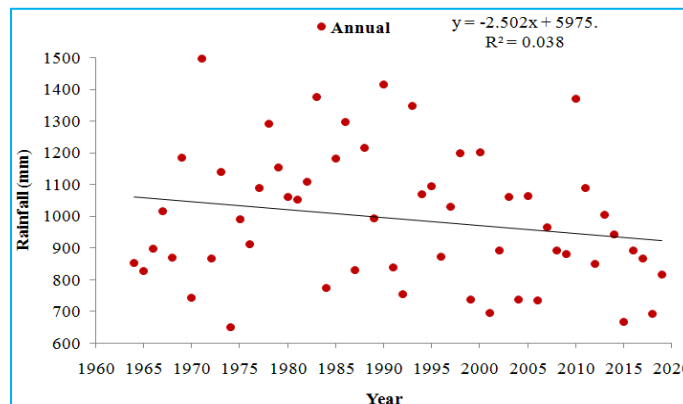

Fig. 8(b). Linear regression trends of annual rainfall for 56 years (1964 to 2019)

4.3. *Seasonal and annual trend using linear regression*

Using a linear regression model [Fig. 8(a)], the rate of change is defined by the slope of regression line which in this case about -2.50, -2.44 and -0.12 mm/year for annual, monsoon and pre-monsoon rainfall, respectively. The declining trend for annual and annual, monsoon and pre-monsoon rainfall was found to be statistically insignificant (Fig. 7). The annual rate of reduction is higher which is caused by the reduction of the main (monsoon) rainfall season [Figs. 8(a&b)]. Annual rainfall observed a decreasing trend having a decrease of 2.50 mm/year [Fig. 8(b)]. This indicates at ICAR-VPKAS, Experimental Farm Hawalbagh meteorological station annual rainfall has decreased by 140 mm during (1964-2019) period.
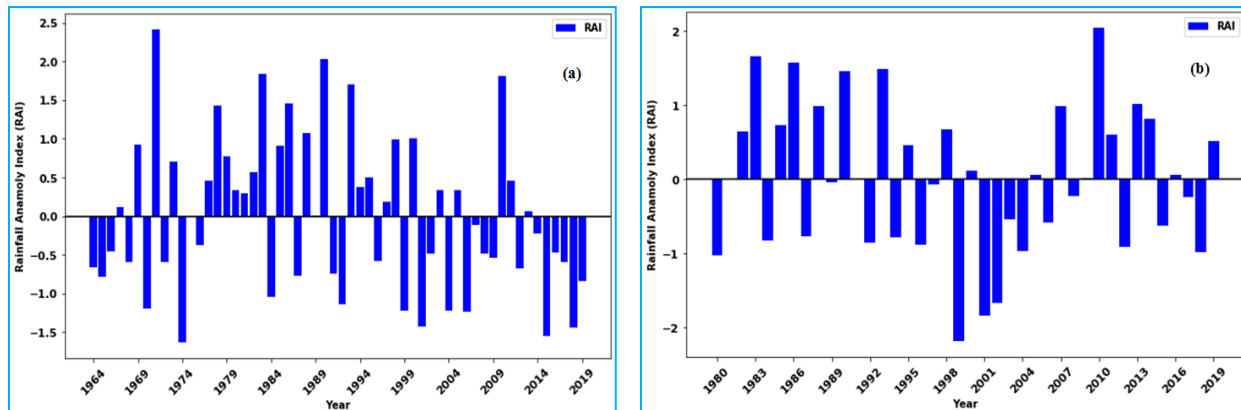
Figs. 9(a&b). RAI of long-term annual rainfall (a) 1964 to 2019 Hawalbagh (b) 1980-2019, Almora

4.4. *Rainfall Anomaly Index (RAI)*

Rainfall Anomaly Index was analysed for a period of 56 years (1964-2019) to identify the years with meteorological drought. It can be observed that the year 2015 took second highest position in rainfall deficit followed by the year 1974 which is remarkable year of severe drought. Indeed 2015 was a dry year, hit by a severe drought [Fig. 9(a)]. RAI for Almora for a period of 39 years (1980-2019) reflects several years having negative RAI as compared to Hawalbagh, Almora as shown in [Fig. 9(b)] but the magnitude is low.

5. Discussions

Also a recent study conducted by Vittal *et al.* (2013) supports our findings that documented the intensified urbanization post-1975 in India as one of the major probable factors in the changing pattern of rainfall extremes over the majority of urban grids; however, not all the urbanized grids show upward trend for extreme events. Similar findings are also supported by Sudhira and Gurruja, 2011 which stated that urbanization and industrialization impact the environment in long term in spatiotemporal manner and its impact is clearly seen in our result the starting of urbanization industrialization in 1980 in Kumaon region in terms of no. of town which has indirect impact on decreasing rainfall in 1990 onward. Rainfall trend was found to be decreasing for the period (1964-2019) in mid-Himalayan region. During the 40 year post-urbanization period (1980-2019), the rate of decrease in annual rainfall is -7.26 mm/year and -2.06 mm/year for pre-monsoon season showing a statistically significant trend at p value <0.01 and p value <0.03, respectively. Observed significant decreasing trend in annual monsoon season in precipitation data can be attributed to the presence of increasing temperature and climate change. The results found in this research agree with previous studies conducted in the Himalaya region (Basistha *et al.*,

2009; Singh *et al.*, 2014; Kumar *et al.*, 2015). This reason attributed to this temporal pattern is due to a number of factors, including significant amount of decrease in the frequency and westerly disturbances from 1971 to 2010 (Singh *et al.*, 2014), increase in human population that indirectly affect the land use (Palazzi *et al.*, 2013; Srivastava *et al.*, 2020b; Maza *et al.*, 2020). The highest rainfall change occurred during annual followed by pre-monsoon season with Sens.'s slope of magnitude of -7.26 mm/year and -2.06 mm/year, respectively. Pre-monsoon (-0.95 mm/year), post-monsoon (-0.02 mm/year) and winter rainfall (-0.45 mm/year) were also found to be decreasing but was not statistically significant. In case of Almora trend during post-urbanization in seasonal as well as monthly rainfall mimics with Hawalbagh, Almora station except April, July, September and November. The study results are reconfirmed with Joshi *et al.* (2013), found decreasing trend in number of rainy at Almora. Large scale deforestation (Gupta *et al.*, 2005), global climate shift (Baines, 2006; Adamala and Srivastava, 2018) are also the possible drivers of this rainfall trend. In addition to this complexity of monsoon system coupled with heterogeneity and adverse topography of Himalayan region remain a controversy around long-term climate changes (Li *et al.*, 2018).

6. Conclusions

In the present study we have analysed the rainfall trend of two observatories one located on hills (Almora, Headquarter) and other located in valley (Hawalbagh, Experimental farm) of Almora to understand the impact of urbanization and industrialization. We observed that rainfall trend after post-urbanization period (1980-2019) at both the place is found to be deceasing. The magnitude of decrease in rainfall trend is found to be more in valley that that of hills. A decreasing monsoonal rainfall, with less decreasing post monsoonal rainfall, infers the shift in the rainfall, probably caused by delayed onset of

monsoon. This may further lead to changes in the cropping period subject to temperature regime. Therefore, from crop production and irrigation requirement point of view, such analysis would certainly aid to water managers and policy planners. Through this paper, we aim to provide comprehensive information of changing rainfall trends covering all major seasons over mid Himalayan region of Uttarakhand, India. This study provides an opportunity to water managers for the preparedness for future water needs in the face of increasing population pressures on water resources and irrigation management. From the results of this study, it is inferred that water resources and agriculture both are at great risk under changing climate in mid-Himalayan region. Furthermore, similar temporal trend analysis could be implemented for other station located in Indian Himalayan Region.

Disclaimer

The contents and views expressed in this research paper/article are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

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