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Research Article

Precipitation Data Analysis and Future Trends in Ludhiana

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ABSTRACT

Rainfall is an important weather element responsible for crop production, ground water recharge, filling of reservoirs, etc. Historic rainfall and rainy days data of Ludhiana (Punjab) was analyzed using various mathematical and statistical techniques to find out trends and variability. The analysis of rainfall data of Ludhiana region for a period of 46 year (1970 to 2015) display a quite good range from 380 to 1334 mm with an annual average rainfall value of 759 mm. The analysis of rainy days data revealed that on an average Ludhiana had 39 rainy days yr^{-1}. The analysis of historical data further revealed that July month had maximum (8.7) rainy days and November month had minimum (0.6) rainy days. After 2000, the number of years with below normal rainfall was 10 and rest of the 5 years had a positive departure from the normal. Similarly, after 2000 the number of years with negative departure in number of rainy days was 6 and rest of the 9 yrs had a positive departure from the normal. The prediction of expected future rainfall and rainy days trend for a period up to 2030 has been made, which indicates a positive trend in rainfall as well as rainy days.

Key words: Rainfall, Environmental impact, Rainy days, Precipitation

Introduction

The meteorological variables such as rainfall and temperature have been affected by global climate change. Any change in the pattern of precipitation can have a significant impact on the availability of water resources, agriculture and the ecosystem. Rain is the primary source of water. Water may be available in the form of surface water or groundwater. On surface it comes from rivers and surface runoff from the land surface. Whereas in groundwater; rainwater get percolated naturally or artificially from surface. Rain water is the purest form of water in nature. In Punjab more than 97% area is irrigated and rest of area is rainfed. Although, in Punjab only 2-3% is dependent on rainfall but due to depleting groundwater resources and deficit canal water supply the Punjab's water resources are greatly influenced by rainfall. However, over the years, the change of land use and urbanization, apart from increasing level of green house gases had disturbed the normal distribution of rain amount over time and space. The total rain amount over certain period is of little use in agriculture as compared to its distribution over time and space that fulfills the crop water requirements especially in dry land regions.

The main source of precipitation is the 'Rain', which generates when drops of water fall to the earth's surface from the atmosphere (clouds). Due to frequent hot days, increased incidence of heavy precipitation events and a shift in winter precipitation from snow to rain have been observed while in southern portion of the Mid-Atlantic, fall precipitation has increased somewhat

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but summer precipitation has decreased. Futuristic models predicted that heavy precipitation events are likely to be more frequent. Thus knowledge of rain amount distribution over time and space is important for crop planning and monitoring. Long term trends of rainfall have been studied by several researchers (Sattar *et al*., 2016; Basistha *et al.*, 2009; Caloiero *et al.*, 2011). Most of the studies are based on the rainfall series constructed by Parthasarathy *et al*. (1994). Long term trends of Indian monsoon rainfall for the country as a whole as well as for smaller areas indicate that the monsoon rainfall has been random in nature over a long period of time (Parthasarathy, 1984; Rupa Kumar *et al*., 1992) it has been observed that the contribution of June, July and September rainfall to annual rainfall is decreasing for few sub-divisions while contribution of August rainfall is increasing in few other subdivisions. So an attempt has been made for time series analysis of rainfall and rainy days in central Punjab to observe the fluctuation in their pattern.

Materials and Methods

The rainfall and rainy days data of Ludhiana for a period of 46 years covering 1970 to 2015 (Table 1 and Table 2) have been collected from meteorological observatory of Department of Climate Change and Agricultural Meteorology, PAU, Ludhiana. The data was analyzed by using both mathematical and statistical techniques of data analysis. The arithmetical procedure involved the determination of average rainfall for a specific period. The departure of rainfall and rainy days from the average rainfall values determines their pattern. Time series analysis was also done and it had been defined as a sequence of values arranged in order of their occurrence which can be characterized by statistical properties (Dawdy and Mathalas, 1964). The commonly used procedures of statistical analysis as followed by Gupta and Kapoor (1985) and Davis (2002) have been followed herein. The computation of statistical parameters included mean, median, mode, dispersion, standard deviation, and coefficient of variation. Based on time series analysis the prediction of future rainfall trend has been attempted as described by Croxten *et al*. (1988).

Different methods used for data analysis and determination of future trend at Ludhiana are given below:

(a) Mathematical method

The mathematical method is most commonly used, which involves calculation of the average of rainfall and rainy days of years or months as shown by the arithmetic mean of the period. For this a suitable mean is required to show the variability of the rainfall. A record of 25 to 50 years is required for rainfall and rainy days data analysis. The mean of a particular distribution is mostly affected by the extreme values and therefore, it is necessary to calculate the median rainfall in the analysis of arithmetic average.

(b) Statistical method

The statistical method employed for the analysis of rainfall and rainy days data of study area for the period from 1970 to 2015, included determinations of central tendencies (mean, median and mode), skewness, dispersion, kurtosis and time series analysis.

(c) Time series analysis

The time series analysis generates valuable information regarding the trend of a series of observations. It helps to measure the deviation from the trend and also provides information pertaining to the nature of the trend. This analysis was used as a tool to forecast the future behavior of the trend. The straight-line equation can be represented as

$$y_c = a + bx$$

where

y_c = Trend value of dependent variable

x = Independent variable

a and b = Constants

(d) Future trend

The future trends of rainfall and rainy days were determined by solving the linear equations. The rainfall was determined as $Y = 2.182X + 708.0$ ($R^2 = 0.015$) and rainy days were

Table 1. Rainfall (mm) at Ludhiana for the period from 1970-2015

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (mm)
1970	29.5	18.0	18.4	0.0	3.3	144.0	50.6	269.8	182.6	2.2	0.0	0.0	718.4
1971	1.0	70.3	0.6	1.1	68.2	115.6	216.8	266.1	20.1	0.0	20.6	0.0	780.4
1972	8.5	41.2	16.8	9.5	0.0	45.1	262.2	102.7	57.6	0.0	12.0	19.0	574.6
1973	43.3	20.3	8.2	1.2	39.0	36.8	163.1	283.2	25.6	4.2	0.0	22.8	647.7
1974	4.2	0.4	2.2	5.0	4.4	142.2	107.6	87.6	20.2	0.0	0.0	5.8	379.6
1975	12.3	14.6	12.2	1.6	1.0	73.6	378.9	166.6	136.6	0.0	0.0	0.0	797.4
1976	65.1	61.5	25.3	9.0	0.0	63.4	242.7	259.4	15.8	0.0	0.0	0.0	742.2
1977	46.0	5.4	0.1	66.8	70.1	61.7	310.2	220.1	117.8	2.4	5.1	41.3	947.0
1978	4.9	23.3	54.2	13.0	2.6	146.7	214.2	115.6	43.1	5.4	7.2	1.0	631.2
1979	20.8	70.3	53.2	27.4	31.2	50.8	132.5	49.8	43.7	0.1	12.7	12.6	505.1
1980	4.8	3.8	34.1	7.3	11.5	41.8	524.8	132.2	30.4	26.4	17.5	79.9	914.5
1981	75.0	16.9	59.1	0.0	7.4	27.4	113.9	162.4	4.3	0.0	85.4	0.0	551.8
1982	50.1	47.0	79.8	56.2	32.5	26.7	199.4	155.1	0.0	0.0	6.7	28.5	682.0
1983	75.6	19.6	12.1	121.9	57.7	27.4	199.9	373.3	68.8	4.1	0.0	1.1	961.5
1984	0.0	76.4	7.2	5.9	0.0	29.4	277.8	291.6	94.0	3.0	0.1	1.4	786.8
1985	0.6	0.0	2.3	19.5	15.7	49.7	367.9	246.4	114.2	27.2	2.2	29.2	874.9
1986	2.2	60.8	79.2	34.6	40.6	105.9	196.3	56.1	56.1	16.6	7.5	3.7	659.6
1987	38.0	20.3	8.1	16.2	80.4	33.9	35.3	95.2	0.0	48.4	0.0	10.4	386.2
1988	3.2	16.3	25.3	0.7	12.5	70.3	432.7	70.3	668.6	0.0	0.0	34.1	1334.0
1989	27.8	10.5	32.5	1.4	0.0	43.6	130.6	136.8	37.0	0.0	17.4	28.9	466.5
1990	2.8	38.4	18.4	0.8	11.8	45.0	258.8	362.6	420.9	4.0	12.4	52.2	1228.1
1991	0.0	24.3	35.8	17.2	9.8	152.3	77.5	106.8	53.9	0.0	0.0	52.9	530.5
1992	83.6	42.4	11.9	6.0	15.6	35.7	172.8	251.3	24.3	0.1	19.0	0.2	662.9
1993	13.0	16.4	30.1	7.3	24.0	21.3	553.1	65.2	117.7	0.0	0.1	0.0	848.2
1994	48.0	34.4	0.9	9.1	0.0	56.6	154.1	318.5	74.0	0.0	0.0	9.6	705.2
1995	49.6	51.1	20.0	19.0	0.0	43.0	190.6	377.7	468.4	0.0	2.6	4.6	1226.6
1996	31.3	69.0	25.7	12.5	2.2	168.3	68.4	279.4	128.8	45.1	0.0	5.0	835.7
1997	18.2	6.8	11.8	32.0	100.2	105.0	94.2	409.8	28.8	24.0	29.0	111.5	971.3
1998	0.0	91.0	13.4	20.4	1.4	91.4	446.9	63.5	143.3	133.2	0.0	0.0	1004.5
1999	54.1	9.4	1.5	0.0	19.1	21.4	359.2	68.6	92.6	0.0	0.0	0.0	625.9
2000	49.7	39.7	20.6	1.4	28.4	89.2	90.6	132.8	139.2	0.0	0.0	0.0	591.6
2001	4.4	0.0	3.4	59.0	30.7	221.0	383.8	213.5	27.8	0.0	0.0	7.2	950.8
2002	6.0	14.0	9.2	15.4	62.6	36.3	36.8	24.5	193.0	2.2	0.0	6.9	406.9
2003	38.1	140.9	21.3	5.8	12.5	49.6	238.0	239.3	52.8	0.0	4.4	8.4	811.1
2004	67.8	0.0	0.0	28.8	52.8	55.4	32.1	225.4	2.6	33.0	1.5	5.7	505.1
2005	48.3	47.4	42.2	0.0	0.0	48.1	183.5	197.6	166.5	0.0	0.0	0.0	733.6
2006	16.8	0.8	32.5	5.1	28.0	40.9	209.2	142.7	103.6	6.8	14.0	8.7	609.1
2007	10.0	84.7	41.3	26.2	6.0	89.2	150.7	112.6	56.8	0.0	1.3	17.7	596.5
2008	16.3	3.2	0.0	50.2	67.3	277.3	149.9	395.6	44.7	39.0	0.4	0.4	1044.3
2009	17.7	21.7	16.0	25.0	6.4	110.6	493.1	118.2	69.2	26.2	5.1	0.0	909.2
2010	18.4	25.0	1.0	4.4	3.8	33.2	381.7	105.8	127.3	8.8	0.0	17.6	727.0
2011	5.4	44.2	6.5	26.5	34.4	352.9	114.2	513.4	177.1	0.0	0.0	11.4	1286.0
2012	52.6	4.6	0.0	38.6	1.6	3.5	76.9	160.4	141.7	1.0	0.0	17.4	498.3
2013	8.2	96.4	35.6	4.4	1.2	296.4	110.2	252.1	37.5	36.2	4.6	13.2	896.0
2014	55.5	36.7	35.0	31.0	26.2	30.2	154.2	89.6	133.8	12.9	0.0	42.2	647.3
2015	24.6	38.6	84.6	29.4	17.0	17.9	256.1	165.6	85.4	16.4	0.0	1.7	737.3
Mean	27.2	34.3	22.8	19.0	22.6	83.2	217.3	194.2	105.4	11.5	6.3	15.5	759.4

Table 2. Rainy days at Ludhiana for the period from 1970-2015

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1970	5	2	1	0	1	6	3	11	9	0	0	0	38
1971	0	6	0	0	4	7	8	6	2	0	1	0	34
1972	2	4	1	2	0	3	8	9	3	0	2	3	37
1973	3	1	1	0	1	5	6	9	3	1	0	2	32
1974	1	0	0	1	0	5	7	6	1	0	0	1	22
1975	2	2	1	0	0	3	10	8	6	0	0	0	32
1976	5	4	3	1	0	5	9	9	2	0	0	0	38
1977	3	1	0	5	4	6	11	8	8	0	1	3	50
1978	1	2	4	1	1	8	11	6	3	1	2	0	40
1979	3	4	3	2	2	4	11	2	3	0	2	2	38
1980	1	1	4	2	2	4	16	10	3	1	2	3	49
1981	5	2	4	0	1	3	9	4	0	0	3	0	31
1982	4	4	9	4	4	3	8	8	0	0	1	2	47
1983	4	3	2	6	5	4	9	11	7	1	0	0	52
1984	0	3	1	1	0	2	12	11	4	1	0	0	35
1985	0	0	0	4	3	3	13	6	4	2	0	2	37
1986	0	5	5	2	4	3	7	3	3	2	1	1	36
1987	2	3	1	3	9	3	3	9	0	1	0	1	35
1988	0	1	2	0	1	3	12	7	8	0	0	2	36
1989	2	1	4	0	0	3	8	6	2	0	2	3	31
1990	1	4	2	0	2	4	11	13	7	1	2	5	52
1991	0	3	1	1	2	5	5	7	4	0	0	3	31
1992	5	3	2	2	1	4	7	10	3	0	1	0	38
1993	2	3	3	1	4	3	12	3	10	0	0	0	41
1994	3	4	0	2	0	4	7	12	7	0	0	2	41
1995	4	3	1	2	0	3	8	16	4	0	0	1	42
1996	3	5	3	2	0	10	5	13	7	2	0	1	51
1997	2	1	3	4	3	7	8	11	3	2	3	3	50
1998	0	5	2	3	0	3	18	5	10	5	0	0	51
1999	5	1	0	0	2	3	10	5	5	0	0	0	31
2000	5	5	2	0	3	4	5	11	5	0	0	0	40
2001	1	0	0	3	2	7	9	4	2	0	0	1	29
2002	1	1	2	1	3	5	3	3	7	0	0	2	28
2003	3	6	2	1	2	5	14	8	3	0	1	1	46
2004	5	0	0	2	1	4	3	11	0	4	0	1	31
2005	2	4	6	0	0	3	9	8	6	0	0	0	38
2006	3	0	3	1	2	6	8	10	2	1	1	1	38
2007	2	9	3	2	2	6	5	5	4	0	0	3	41
2008	2	0	0	4	4	10	9	10	4	2	0	0	45
2009	2	3	3	2	1	3	12	6	3	1	1	0	37
2010	2	1	0	1	1	3	16	7	10	1	0	2	44
2011	1	3	1	2	3	8	8	11	7	0	0	2	46
2012	4	2	0	8	0	0	7	12	7	0	0	2	42
2013	1	8	2	1	0	7	5	8	3	2	1	2	40
2014	3	3	5	1	4	2	6	5	7	3	0	1	40
2015	3	4	7	2	3	3	10	7	4	2	0	0	45
Average	2.3	2.8	2.2	1.8	1.9	4.5	8.7	8.0	4.5	0.8	0.6	1.3	39.3

determined as Y = 0.110X + 36.71 (R^2 = 0.043) and these equations were developed by using historical data (1970-2015). The year was considered as X variable in the equation to predict values of rainfall and rainy days for future upto 2030.

Results and Discussion

Rainfall and rainy days trends

The data on rainfall (mm) and rainy days during different months and years (1970-2015) is presented in Table 1 and 2, respectively. The average rainfall and rainy days of the study area were calculated as 759 mm/year and 39 days/year. The lowest (379.6 mm) and highest (1334.0 mm) rainfall was recorded during 1974 and 1988, respectively. Lowest (22) number of rainy days were recorded during 1974. Similarly, the highest (52) number of rainy days were recorded during 1983 and 1990.

At Ludhiana July month followed by August had maximum quantity of rainfall and rainy days, whereas, November month had minimum rainfall and number of rainy days (Fig 1). It was also found that >50 mm rainfall occurs during monsoon months and <50 mm in pre-monsoon and post-monsoon months (Fig 1).

The yearly analysis of total annual rainfall and rainy days (Fig. 2) revealed a statistically non significant but an increasing trend of both parameters. The annual rainfall is increasing at a rate of 2.18 mm/year. Similarly, the annual number of rainy days is increasing at a rate of 0.11 days/year.

The seasonal analysis of rainfall data (Table 3) revealed that *kharif* season (April to

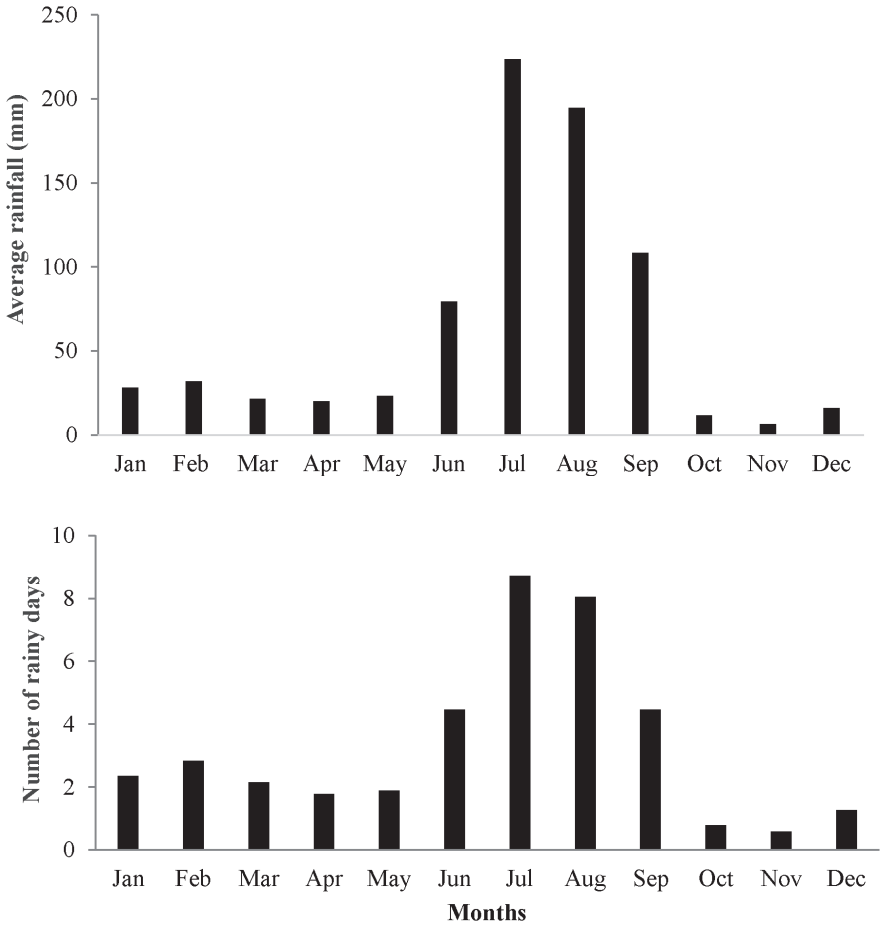

Fig. 1. Average monthly rainfall & rainy days at Ludhiana during 1970 to 2015

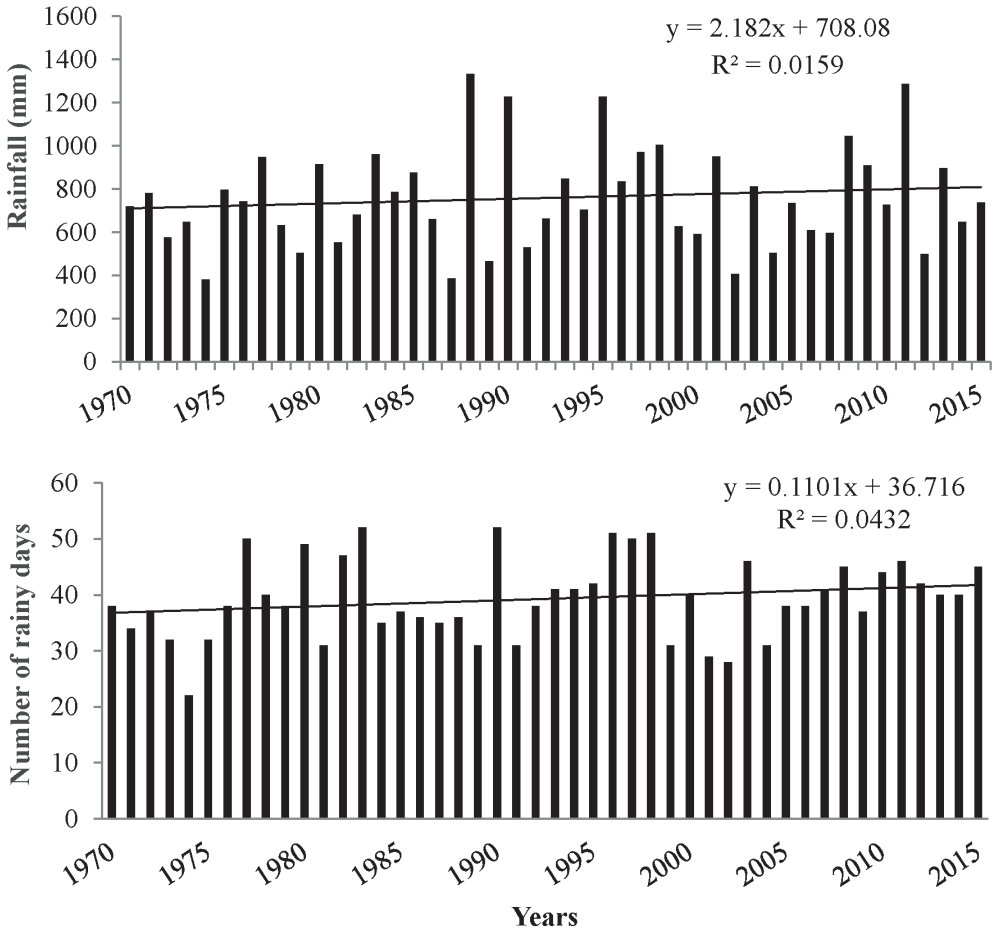

Fig. 2. Total rainfall (mm) and number of rainy days at Ludhiana during 1970-2015

September) had maximum (646.0 mm) rainfall. The monsoon season had 604.4 mm of rainfall during a period of four months (June to September). Winter season had minimum rainfall (6.4 mm) at Ludhiana. The seasonal analysis of rainy day data (Table 3) revealed that *kharif* season had maximum (29.3) number of rainy days as compared to other seasons. The monsoon season had 25.7 rainy days. Winter season had minimum number of rainy days (6.4) at Ludhiana. Further it has been observed that the *kharif, rabi* and monsoon season rainfall (Fig. 3) and rainy days (Fig. 4) showed a statistically non significant increasing trend over the past 46 years. However, among the three (*kharif, rabi* and monsoon) seasons, monsoon season rainfall had highest increasing trend of rainfall and rainy days and the rate of increase was 1.69 mm/year and 0.042 days/year, respectively.

The annual rainfall and rainy days departure has been shown in (Fig. 5). The number of years having below average (759.3 mm) rainfall was 26 and the number of years having positive departure from normal were 20 during the study period. The years having below normal rainfall were 1970, 1972, 1973, 1974, 1976, 1978, 1979, 1981, 1982, 1986, 1987, 1989, 1991, 1992, 1994, 1999, 2000, 2002, 2004, 2005, 2006, 2007, 2010, 2012, 2014 and 2015. Whereas, the years having above normal rainfall were 1971, 1975, 1980, 1977, 1983, 1984, 1985, 1988, 1990, 1993, 1995, 1996, 1997, 1998, 2001, 2003, 2008, 2009, 2011, and 2013. These years are favorable for groundwater recharge. Average of rainfall deficit (normal-annual rainfall) during these 26 years was 162.3 mm. However, the average of above normal (annual -normal rainfall) rainfall was 211.0. This highlights that the deviation towards lower side

Table 3. Average monthly and seasonal rainfall and no of rainy days at Ludhiana

Season	Months	Mean monthly rainfall (mm)	Mean monthly No of rainy days	Total seasonal rainfall (mm)	Total seasonal no of rainy days
Monsoon	June	81.00	4.5	604.4	25.7
	July	220.31	8.7		
	August	195.94	8.0		
	September	106.78	4.5		
Winter	December	15.28	1.3	75.08	6.4
	January	27.09	2.3		
	February	32.70	2.8		
Summer	April	18.81	1.8	123.00	8.1
	May	23.18	1.9		
	June	81.00	4.5		
Rabi	October	10.78	0.8	113.27	10.0
	November	6.61	0.6		
	December	15.28	1.3		
	January	27.09	2.3		
	February	32.70	2.8		
	March	20.80	2.2		
Kharif	April	18.81	1.8	646.03	29.3
	May	23.18	1.9		
	June	81.00	4.5		
	July	220.31	8.7		
	August	195.94	8.0		
	September	106.78	4.5		

Total annual rainfall = 759.30 mm, Total annual rainy days = 39.3

of annual rainfall from normal is less in quantity as compared to its deviation towards higher side. After 2000 the number of years with below normal rainfall were 10 (2002, 2004, 2005, 2006, 2007, 2010, 2012, 2014 and 2015) and rest of the 5 years had positive departure. Similarly, after 2000 the number of years with negative departure in number of rainy days were 6 (2001, 2002, 2004, 2005, 2006 and 2009) and rest of the 9 years had positive departure. So there existed dissimilarity among the number of years of deficit and excess rainfall and rainy days. Number of years with deficit rainfall may be having above normal number of rainy days and vice versa.

The trend analysis (1970-2015) of monthly rainfall and rainy days data is presented in Table 4. The rainfall showed a slight decreasing (statistically non-significantly) trend during May, July, November and December by 0.03, 0.67, 0.23 and 0.07 mm/year. However, rest of the months had a slight increasing but statistically non-significantly trend. The data on monthly number of rainy days did not exhibit any significant trend except during the months of October and November. During the month of October the number of rainy days exhibited a statistically significant (at 5% level of probability) and increasing trend. During October number of rainy days is increasing at a rate of 0.03 days/year. However, during the month of November, number of rainy days exhibited a statistically significant (at 5% level of probability) and decreasing trend. During November month the number of rainy days is decreasing at a rate of 0.02 days/year. Apart from these months, the number of rainy days showed a slight decreasing (statistically non-

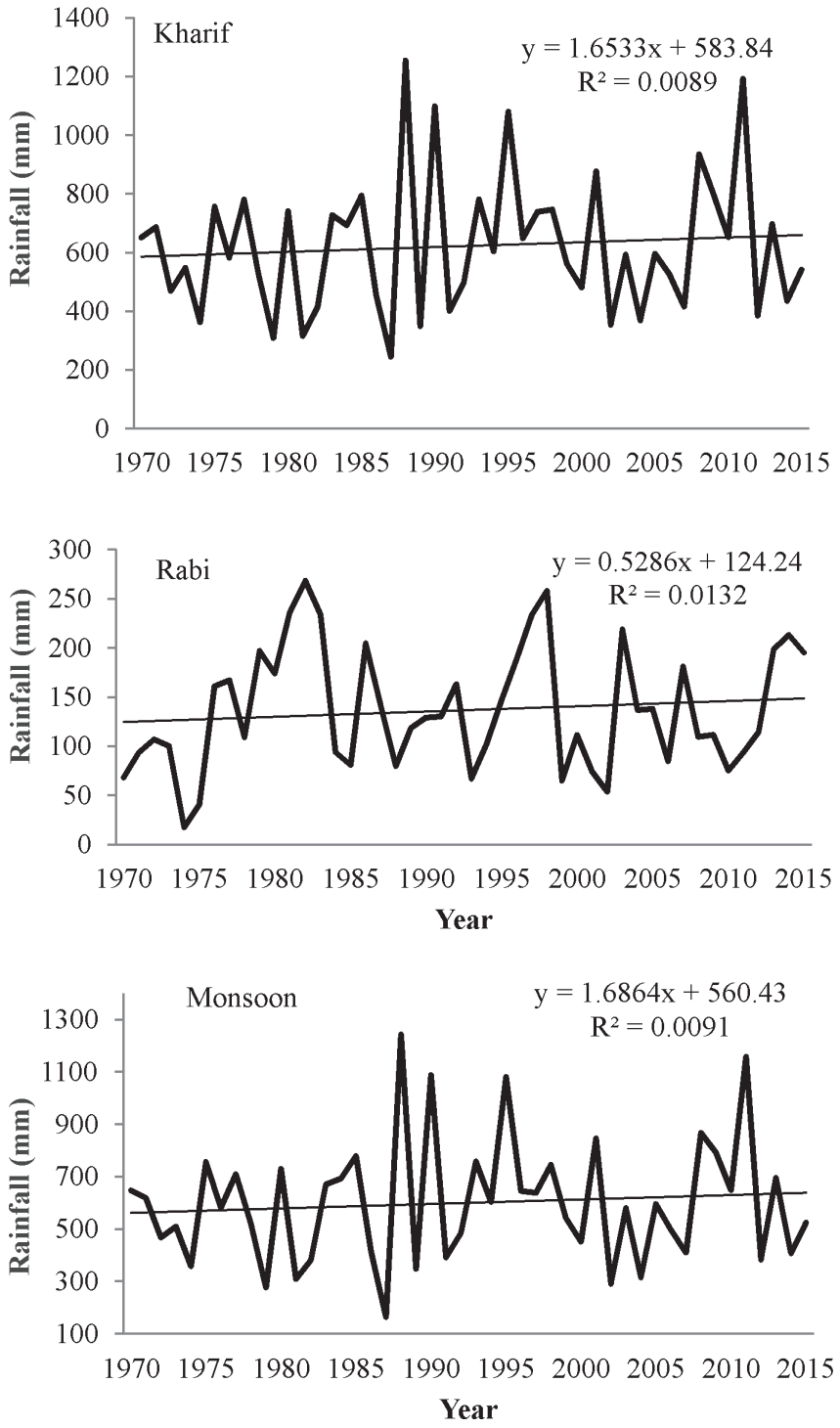

Fig. 3. Trends of rainfall at Ludhiana during *kharif*, *rabi* and monsoon seasons (1970-2015)

significantly) trend during July and December months and rest of the months had a slight increasing but statistically non-significantly trends.

Statistical analysis of rainfall and rainy days data

The statistical analysis of rainfall and rainy days data was also performed (Table 5 and 6).

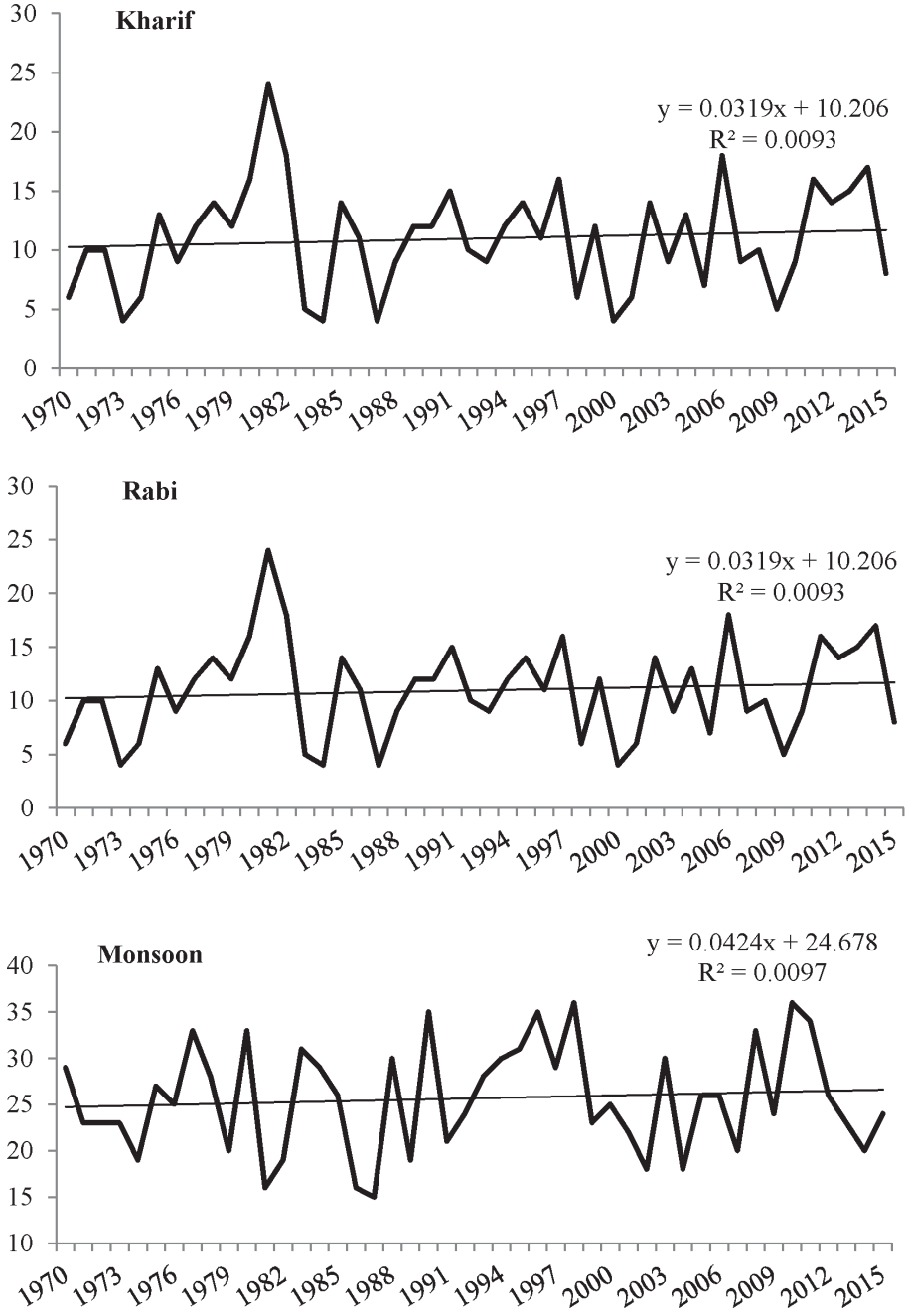

Fig. 4. Trends of rainy days at Ludhiana during *kharif*, *rabi* and monsoon seasons (1970-2015)

The frequency distribution (Table 5) of rainfall data showed that 550-750 mm class had maximum frequency of 18 and was followed by 11 in the class interval of 750-950 mm. Similarly, the data on frequency distribution of rainy days showed that class interval of 30-40 days had maximum frequency of 21 and was followed by 16 in the class interval of 40-50 days.

The data (Table 6) revealed that the mean rainfall of the area is 759.3 mm in 39.3 rainy days. The computed value of mode for rainfall and rainy days is 505.3 mm and 38.0, respectively. The calculated value of standard deviation revealed that deviation of rainfall and rainy days is 231.4 mm and 7.11 days, respectively. The coefficient of skewness has been

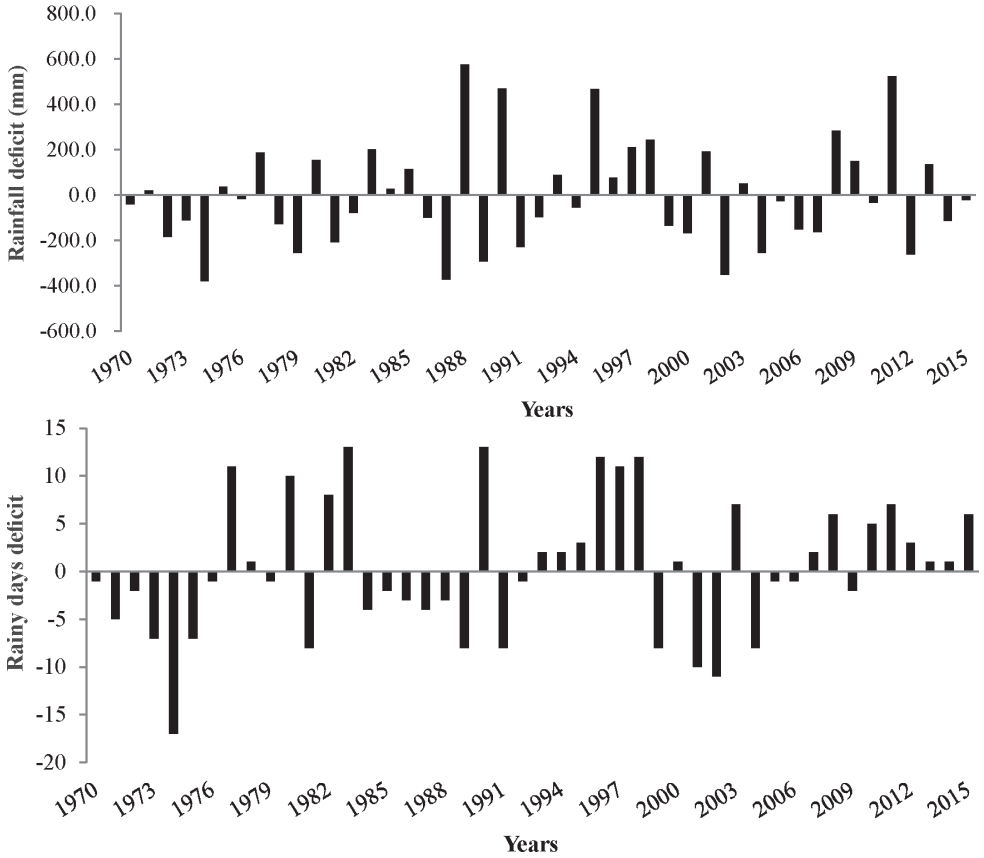

Fig. 5. Departure from normal rainfall (mm) and number rainy days at Ludhiana

Table 4. Monthly rainfall and rainy days trends during 1970-2015

Month	Rainfall	No. of rainy days
January	Y = 0.0721x + 25.552 R^2 = 0.0016	Y = 0.0039x + 2.2551 R^2 = 0.0011
February	Y = 0.247x + 28.5 R^2 = 0.0114	Y = 0.02x + 2.3565 R^2 = 0.0165
March	Y = 0.0002x + 22.812 R^2 = 0.0008	Y = 0.0139x + 1.8261 R^2 = 0.0085
April	Y = 0.1603x + 15.229 R^2 = 0.0087	Y = 0.0202x + 1.3072 R^2 = 0.0248
May	Y = -0.033x + 23.409 R^2 = 0.0003	Y = 0.0027x + 1.829 R^2 = 0.0004
June	Y = 1.1135x + 57.044 R^2 = 0.0383	Y = 0.0012x + 4.429 R^2 = 0.0000
July	Y = -0.666x + 232.91 R^2 = 0.0043	Y = -0.0096x + 8.942 R^2 = 0.0014
August	Y = 0.3375x + 186.26 R^2 = 0.0016	Y = 0.0097x + 7.8145 R^2 = 0.0018
September	Y = 0.9015x + 84.211 R^2 = 0.0093	Y = 0.041x + 3.4928 R^2 = 0.0399
October	Y = 0.3526x + 3.2122 R^2 = 0.0427	Y = 0.0269x + 0.1507 R^2 = 0.098 *
November	Y = -0.2331x + 11.755 R^2 = 0.0510	Y = -0.0183x + 1.0174 R^2 = 0.0774 *
December	Y = -0.0704x + 17.181 R^2 = 0.0017	Y= -0.0015x + 1.2957 R^2 = 0.0003

*significant at 5% level of probability

Table 5. Frequency distribution of rainfall and number of rainy days at Ludhiana

Rainfall		Rainy days	
Class interval (mm)	Frequency (f)	Class interval (number)	Frequency (f)
350-550	8	20-30	3
550-750	18	30-40	21
750-950	11	40-50	16
950-1150	5	50-60	6
1150-1350	4		
Total	46		46

Table 6. Statistical parameters of rainfall and rainy days data of the Ludhiana

Statistical parameter	Computed value (Rainfall)	Computed value (Rainy days)
Mean	759.3	39.3
Median	730.3	38.0
Mode	505.1	38.0
Standard deviation	232.4	7.1
Coefficient of dispersion	0.30	0.18
Coefficient of variation	30.6	18.1
Coefficient of skewness	1.1	0.18

worked out as 1.10 and 0.18, for rainfall and rainy days respectively. It indicated a positive skewness in the both data sets.

Table 7. Expected future trend of rainfall and rainy days at Ludhiana

Year	Expected future trend	
	Rainfall (mm)	Number of rainy days
2019	804.90	42.10
2020	807.59	42.21
2021	810.28	42.32
2022	812.96	42.43
2023	845.24	42.54
2024	847.93	42.65
2025	850.61	42.76
2026	853.30	42.87
2027	855.99	42.98
2028	858.67	43.09
2029	861.36	43.20
2030	864.04	43.31

Future trends

The future trends (Table 7) of rainfall and rainy days indicate an increasing trend in rainfall as well as rainy days. Rainfall may reach a value of 864.0 mm during 2030 and rainy days may increase by 4 as compared to normal (39.3) and would reach upto 43.3 at Ludhiana during 2030.

Environmental impacts of rainfall

The rainfall is one of the most important meteorological parameter that acts as a main source for the recharge of ground water system besides other environmental impacts. The analysis of rainfall data of Ludhiana region showed slight but statistically non significant variation in rainfall trends from 1970-2015 but 2000 onwards frequency of negative trend is more as compared to positive trend that can be one of the reason for depletion of ground water levels. The present trend of over exploitation of ground water due to population growth, industrialization, irrigation and lesser rainfall than the annual average value are affecting the recharge of ground water, which are depleting at an alarming rate.

Conclusion

The rainfall data analysis of Ludhiana region for a period of 46 years from 1970 to 2015 reveals variation in the amount and frequency of rainfall as well as rainy days. It further pointed out a statistically non significant but increasing (2.18 mm/year and 0.11 days/year) trend in annual rainfall and rainy days. The analysis revealed that Ludhiana has normal rainfall of 759.3 mm in 39.3 rainy days. After 2000 the number of years with below normal rainfall were 10 (2002, 2004, 2005, 2006, 2007, 2010, 2012, 2014 and 2015) and rest

of the 5 years had positive departure from normal. Similarly, after 2000 the number of years with negative departure in number of rainy days were 6 (2001, 2002, 2004, 2005, 2006 and 2009) and rest of the 9 years had positive departure.

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