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50 year rainfall data analysis and future trend in Saharanpur region

VARTIKA SINGH and PRAMENDRA DEV*

SRF in DTRL, Defence Research and Development Organization, New Delhi – 110 054, India

**Prof. in, School of Studies in Earth Science, Vikram University, Ujjain – 456 010, India*

(*Received 17 September 2010*)

e mail : vartika_vartu@yahoo.co.in; drpdev@yahoo.com

सार – इस शोध पत्र में पश्चिमी उत्तर प्रदेश में स्थित सहारनपुर क्षेत्र की भूजल प्रणाली के फिर से भरने में वर्षा जल के पैटर्न के पर्यावरणीय प्रभावों का अध्ययन किया गया है। सहारनपुर क्षेत्र में 50 वर्ष (1959 से 2008) की वर्षा असमानता के गणितीय विश्लेषण से 1209.8 मि.मी. के वार्षिक औसत वर्षा मान और 497.70 से 4357.5 मि. मी. तक की काफी अच्छी रेंज का पता चला है। औसत वार्षिक वर्षा के कंप्यूटर मान से विचलन की सकारात्मक प्रवृत्ति भू जल जलाश्य के पुनः भरण की समुचित अवधियाँ दर्शाते हैं। पिछले 03 वर्ष के दौरान वार्षिक वर्षा के रिकॉर्ड किए गए आँकड़ें आकलित वार्षिक औसत वर्षा से कम मान दर्शाते हैं जिससे वर्षा की नकारात्मक प्रवृत्ति का पता चलता है। वर्षा के आँकड़ों के सांख्यिकीय विश्लेषण में विभिन्न सांख्यिकीय प्राचलों के परिकलन शामिल हैं जिससे भी वर्षा की नकारात्मक प्रवृत्ति का पता चलता है। वर्ष 2018 तक की अवधि के लिए भविष्य में वर्षा की संभावित प्रवृत्ति का पूर्वानुमान लगाया गया है जिससे वर्षा की नकारात्मक प्रवृत्ति का पता चलता है। भूजल संसाधन की वृद्धि के लिए योजना कार्यान्वित करने और वर्षा के जल के संग्रहण की संभावनाओं का विकास करने के लिए भी इस प्रस्ताव को शामिल किया गया है।

ABSTRACT. The environmental implications of rainfall pattern in replenishment of ground water system of Saharanpur region, located in western Uttar Pradesh, have been discussed. The mathematical analysis of rainfall dissimilarity of Saharanpur region for a period of 50 year (1959 to 2008) display a quite good range from 497.70 to 4357.5 mm with an annual average rainfall value of 1209.8 mm. The positive trend of departure from the computer value of average annual rainfall exhibits appropriate periods for recharge of ground water reservoir. The recorded data of annual rainfall during the last 3 year reveal values below the calculated annual average rainfall, pointing out negative trend. The statistical analysis of rainfall data involves computations of various statistical parameters, which also support the negative trend of rainfall. The prediction of expected future rainfall trend for a period up to 2018 has been made, which indicates a negative trend. The proposal have been incorporated to implement a plan for augmentation of ground water resource and also to develop possibilities of rainwater harvesting.

Key words – Rainfall, Environmental impact, Rainwater harvesting, Precipitation.

1. Introduction

The term 'Rainfall' is most commonly applied for the liquid precipitation. According to Navarra (1979), rainfall is usually referred to "The amount of precipitation of any type usually taken as that amount which is measured by means of a rain gauge thus a small varying amount of direct condensation is included". Precipitation is the liquid water particles, either in the form of drops of more than 0.5 mm diameter or in the form of smaller widely scattered drops (Lal, 2002). The main source of precipitation is the 'Rain', which generates when separate drops of water fall to the earth's surface from the atmosphere (clouds).

The amount of raindrop is measured using a rain gauge. It is expressed as the depth of water that collects on a flat surface, and is measured with accuracy up to 1,000,000 cloud droplets are equal to 1 drop of rain that is falling down to the ground surface. The clouds have sometimes to do with rain too. Singh (2009) remarked that the small raindrops less than about 2 mm diameters are approximately spherical. As they get larger to about 5 mm diameter they become nut shape beyond 5 mm, they

TABLE 1

Rainfall data of Saharanpur region for the period from 1959-2008, values are recorded in mm

S. No.	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (mm)
1	1959	82.90	4.30	11.50	-	10.00	44.20	546.30	539.80	234.60	44.20	25.40	25.40	1568.60
2	1960	52.00	45.40	4.60	-	-	224.30	429.60	285.90	129.10	28.70	-	10.00	1209.60
3	1961	171.50	47.00	-	25.40	8.30	157.20	537.40	525.60	82.00	80.50	-	25.00	1659.90
4	1962	111.90	76.80	40.60	-	-	44.90	331.40	160.20	254.50	-	33.80	38.20	1092.30
5	1963	22.30	21.00	4.90	-	15.70	71.60	208.20	518.80	251.70	0.50	15.80	9.40	1139.90
6	1964	23.50	1.50	7.60	0.50	50.70	50.10	825.70	417.10	349.00	-	-	16.30	1742.00
7	1965	59.90	97.00	32.30	22.00	76.95	-	564.30	226.10	10.20	49.00	-	2.30	1140.05
8	1966	4.10	21.80	16.30	0.80	57.70	188.00	523.00	489.50	93.40	25.00	-	15.20	1434.80
9	1967	-	0.80	97.00	0.50	5.60	8.70	338.50	648.30	38.10	30.70	10.40	24.40	1203.00
10	1968	34.00	18.00	28.60	-	1.00	146.30	594.50	331.10	103.40	13.60	-	20.80	1291.30
11	1969	9.60	17.60	29.80	14.50	6.50	8.60	283.30	341.60	166.20	-	-	-	877.70
12	1970	83.20	21.20	5.60	8.20	27.80	173.90	92.00	254.50	134.40	1.80	-	-	802.60
13	1971	15.60	18.10	-	23.00	68.20	204.90	386.70	405.30	125.60	55.00	-	-	1302.40
14	1972	23.00	63.00	-	35.50	-	209.50	121.30	117.00	126.70	2.60	24.40	14.20	737.20
15	1973	20.00	14.01	-	-	15.30	507.10	466.20	31.00	31.70	137.50	-	18.00	1240.81
16	1974	6.50	-	-	-	24.70	62.90	405.60	91.80	12.00	12.50	-	63.60	679.60
17	1975	47.20	23.40	13.80	7.50		237.20	412.00	253.70	191.30	31.00	-	-	1217.10
18	1976	17.30	46.80	18.30	1.50	32.50	107.50	449.50	516.50	40.50	-	-	-	1230.40
19	1977	40.50	-	-	20.00	7.50	309.20	522.70	182.70	227.00	20.00	-	57.50	1387.10
20	1978	-	80.60	150.00	8.00	-	195.80	437.20	999.00	390.00	-	2.00	-	2262.60
21	1979	27.10	99.70	14.00	12.50	55.30	136.20	344.50	62.80	40.40	58.40	-	29.90	822.40
22	1980	22.40	11.40	11.60	4.40	67.40	148.80	360.90	272.70	47.60	57.20	47.20	42.40	1095.20
23	1981	44.80	3.40	60.00	19.80	15.60	28.70	348.60	62.40	36.00	3.30	-	6.00	682.50
24	1982	68.40	68.90	69.90	61.50	51.90	48.80	168.30	254.20	6.90	4.80	0.90	59.40	810.50
25	1983	102.60	23.50	7.20	124.10	31.60	48.30	607.80	436.90	59.60	-	-	8.20	1454.60
26	1984	59.40	115.40	-	3.80	-	289.00	307.50	251.30	48.40	154.90	-	-	1074.80
27	1985	11.20	-	1.00	21.20	1.40	89.20	298.00	188.30	139.20	12.50	-	50.60	955.00
28	1986	-	89.00	12.50	10.20	78.10	110.70	188.40	217.90	118.20	0.40	19.60	37.40	895.40
29	1987	27.80	37.40	25.30	47.80	112.10	85.40	64.70	44.60	40.80	-	-	11.40	497.70
30	1988	0.60	37.50	81.50	2.00	22.30	84.00	503.00	502.50	261.20	-	-	71.50	1566.10
31	1989	76.00	25.00	8.00	1.50	15.00	58.50	328.50	503.50	80.50	16.00	20.50	98.00	1215.00
32	1990	-	118.00	33.00	7.00	20.00	23.00	45.00	376.50	320.50	-	12.00	113.50	1084.50
33	1991	-	38.50	21.80	15.50	8.50	105.70	116.20	132.50	134.00	-	-	39.50	612.20
34	1992	42.00	47.00	4.50	9.20	0.20	21.50	302.10	617.30	77.70	-	10.40	-	1131.90
35	1993	56.10	34.50	73.50	-	32.50	73.70	384.20	372.60	372.60	-	30.00	-	1429.70
56	1994	48.00	42.50	10.00	49.00	21.80	106.10	457.90	291.50	80.50	-	-	0.58	1107.88
37	1995	48.50	64.50	11.00	12.00	-	98.00	422.00	492.00	159.50	0.50	1.00	-	1309.00
38	1996	24.00	79.00	24.00	2.50	10.50	159.00	24.50	3790.00	150.50	93.50	-	-	4357.50
39	1997	18.50	1.00	4.00	127.50	13.50	64.00	582.50	100.00	164.50	43.00	40.50	83.50	1242.50
40	1998	2.50	25.00	10.50	39.50	42.50	168.00	315.00	242.00	139.00	132.50	-	-	1116.50
41	1999	77.50	30.00	9.00	-	22.50	81.50	320.50	363.00	250.00	-	-	3.00	1157.00
42	2000	40.00	65.00	26.00	38.00	29.50	29.50	315.00	220.00	13.00	-	-	-	776.00
43	2001	16.00	2.00	30.50	16.50	72.50	274.00	441.00	168.00	2.00	2.00	1.00	5.00	1030.50
44	2002	27.50	110.50	4.00	23.00	15.00	166.50	183.50	194.50	287.50	10.00		0.50	1022.50
45	2003	70.50	37.50	-	12.50	7.00	81.20	312.00	209.00	109.00	-	8.00	12.00	858.70
46	2004	83.00	-	67.00	19.00	70.50	299.50	168.50	42.00	48.50	5.50	0.50	804.00	1608.00
47	2005	42.50	31.50	79.50	2.00	1.00	463.00	277.00	102.00	441.00	-	-	-	1439.50
48	2006	10.50	-	58.00	0.50	136.00	129.50	351.80	61.50	42.70	27.00	-	10.00	827.50
49	2007	-	114.50	53.00	11.60	35.00	258.00	221.00	134.00	134.00	-	-	4.00	965.10
50	2008	11.00	1.00	-	15.00	26.00	400.00	232.00	292.00	111.00	24.00	17.20	-	1129.20
		1926.20	2015.32	1302.20	897.878	1456.758	7225.714	17816.65	18699.66	7045.85	1214.92	337.47	1882.99	60493.84

Annual Average Rainfall = 1209.8

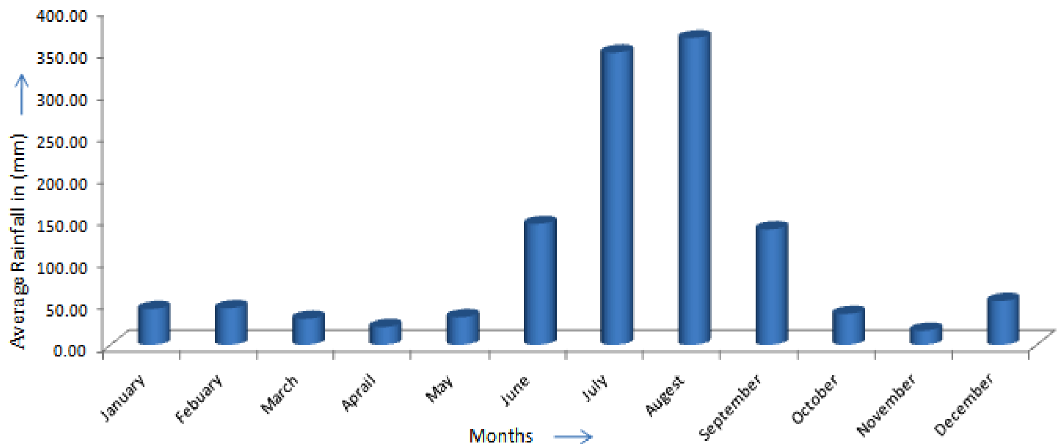

Fig. 1. Average monthly rainfall of Saharanpur region during 1959 to 2008

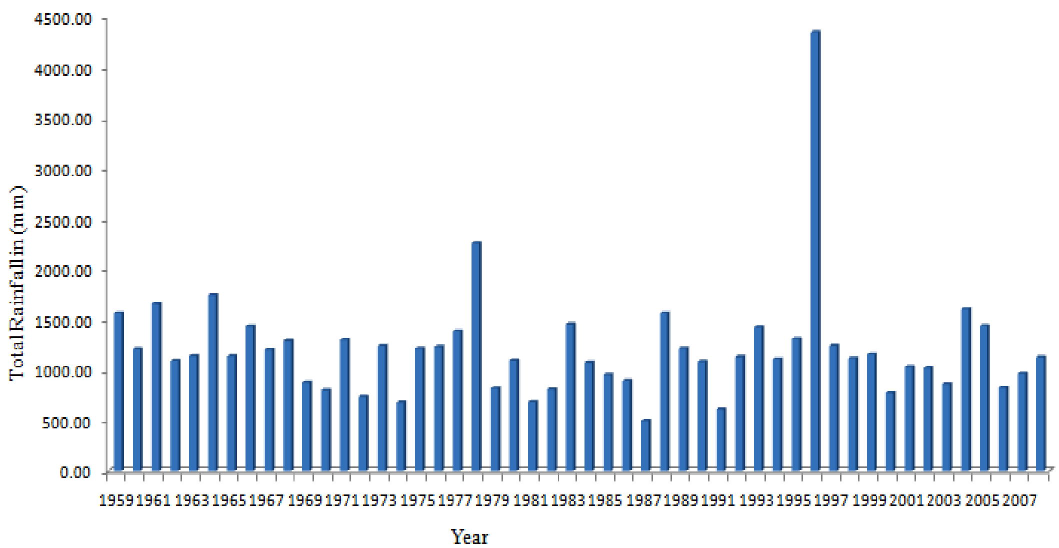

Fig. 2. Total rainfall of Saharanpur region during 1959 to 2008

become unstable and fragmented. On average the diameter of raindrops is 1 mm to 2 mm, and the biggest raindrops on the earth are resulted due to condensation of large smoke particles or by collisions between drops in small regions with particularly high content of liquid water. Rainfall is commonly measured with the help of rain gauge and the values are expressed in millimeter or inches. The rain gauges are mainly classified into two categories - (a) Non-recording type rain gauge and (b) Recording type rain gauge. The rainfall shows variation from place to place, even during a period of single storm. The period of rainfall record may be a minute, an hour, a day, a month or a year. The affecting factors of rainfall intensity are involved in all measurements and the period is expressed by the term annual, monthly, daily or hourly precipitation. The rate of rainfall is noted from the computation for a particular day or multiple numbers of days from the records of daily reading of standard gauge. The storage gauges are used for long-term measurements.

2. Rainfall data analysis of study area

The rainfall data of Saharanpur area for a period of 50 years covering 1959 to 2008 (Table 1, Figure 2) have been collected from Meteorological Department, Muzafarrabad, Saharanpur district and analyzed by using both mathematical and statistical techniques of data analysis. The arithmetical procedure involves the determination of average rainfall for a specific period. The

TABLE 2

Time series analysis of rainfall data of Saharanpur region during 1960 – 2008

S. No.	Year	x	y	x^2	xy	x^3	x^2y	x^4	Trend value
1	1960	-24	1209.6	576	-29030.4	-13824	696729.6	331776	936.928
2	1961	-23	1659.9	529	-38177.7	-12167	878087.1	279841	947.989
3	1962	-22	1092.3	484	-24030.6	-10648	528673.2	234256	959.05
4	1963	-21	1139.9	441	-23937.9	-9261	502695.9	194481	970.111
5	1964	-20	1742	400	-34840	-8000	696800	160000	981.172
6	1965	-19	1140.05	361	-21660.95	-6859	411558.05	130321	992.233
7	1966	-18	1434.8	324	-2606.4	-5832	464875.2	104976	1003.294
8	1967	-17	1203	289	-20451	-4913	347667	83521	1014.355
9	1968	-16	1291.3	256	-20660.8	-4096	330572.8	65536	1025.416
10	1969	-15	877.7	225	-13165.5	-3375	197482.5	50625	1036.477
11	1970	-14	802.6	196	-11236.4	-2744	157309.6	38416	1047.538
12	1971	-13	1302.4	169	-16931.2	-2197	220105.6	28561	1058.599
13	1972	-12	737.2	144	-8846.4	-1728	106156.8	20736	1069.66
14	1973	-11	1240.81	121	-13648.91	-1331	150138.01	14641	1080.721
15	1974	-10	679.6	100	-6796	-1000	67960	10000	1091.782
16	1975	-9	1217.1	81	-10953.9	-729	98585.1	6961	1102.843
17	1976	-8	1230.4	64	-9843.2	-812	787456	4096	1113.904
18	1977	-7	1387.1	49	-9709.7	-343	67967.9	2401	1124.965
19	1978	-6	2262.6	36	-13575.6	-216	81453.6	1296	1136.026
20	1979	-5	822.4	25	-4112	-125	20560	625	1147.087
21	1980	-4	1095.2	16	-4380.8	-64	17523.2	256	1158.148
22	1981	-3	682.5	9	-2047.5	-27	6142.5	81	1169.209
23	1982	-2	810.5	4	-1621	-8	3242	16	1180.27
24	1983	-1	1454.6	1	-1454.6	-1	1454.6	1	1191.331
25	1984	0	1074.8	0	0	0	0	0	1202.392
26	1985	1	955	1	955	1	955	1	1213.453
27	1986	2	895.4	4	1790.8	8	35816	16	1224.514
28	1987	3	497.7	9	1493.1	27	4479.3	81	1235.575
29	1988	4	1566.1	16	6264.4	64	25057.6	256	1246.636
30	1989	5	1215	25	6075	125	30375	625	1257.697
31	1990	6	1084.5	36	6507	216	39042	1296	1268.758
32	1991	7	612.2	49	4285.4	343	29997.8	2401	1279.819
33	1992	8	1131.9	64	90552	812	72441.6	4096	1290.88
34	1993	9	1429.7	81	12867.3	729	115805.7	6961	1301.941
35	1994	10	1107.88	100	11078.8	1000	110788	10000	1313.002
36	1995	11	1309	121	14399	1331	158389	14641	1324.063
37	1996	12	4357.5	144	52290	1728	627480	20736	1202.392
38	1997	13	1242.5	169	16152.5	2197	209982.5	28561	1346.185
39	1998	14	1116.5	196	15631	2744	218834	38416	1357.246
40	1999	15	1154	225	17310	3375	259650	50625	1368.307
41	2000	16	771	256	12336	4096	197376	65536	1379.368
42	2001	17	1030.5	289	17518.5	4913	297814.5	83521	1390.429
43	2002	18	1022.5	324	18405	5832	331290	104976	1401.49
44	2003	19	858.7	361	16315.3	6859	309990.7	130321	1412.551
45	2004	20	1608	400	32160	8000	643200	160000	1423.612
46	2005	21	1439.5	441	30229.5	9261	634819.5	194481	1434.673
47	2006	22	827.5	484	18205	10648	400510	234256	1445.734
48	2007	23	965.1	529	22197.3	12167	510537.9	279841	1456.795
49	2008	24	1129.2	576	27100.8	13824	650419.2	331776	1467.856
		$\sum x = 0$	$\sum y = 58917.24$	$\sum x^2=9800$	$\sum xy = 108400.24$	$\sum x^3 = 0$	$\sum x^2y = 12756247.56$	$\sum x^4 = 3526840.00$	

TABLE 3

Annual rainfall, its departure and cumulative departure from average annual rainfall in Saharanpur during 1959-2008

S. No.	Year	Total rainfall (mm)	Departure from average rainfall	Cumulative Departure from average rainfall
1	1959	1568.6	358.8	358.8
2	1960	1209.6	-0.2	358.6
3	1961	1659.9	450.1	808.7
4	1962	1092.3	-117.5	691.2
5	1963	1139.9	-69.9	621.3
6	1964	1742	532.2	1153.5
7	1965	1140.05	-69.75	1083.75
8	1966	1434.8	225	1308.75
9	1967	1203	-6.8	1301.95
10	1968	1291.3	81.5	1383.45
11	1969	877.7	-332.1	1051.35
12	1970	802.6	-407.2	644.15
13	1971	1302.4	92.6	736.75
14	1972	737.2	-472.6	264.15
15	1973	1240.81	31.01	295.16
16	1974	679.6	-530.2	235.04
17	1975	1217.1	7.3	227.74
18	1976	1230.4	20.6	207.14
19	1977	1387.1	177.3	29.84
20	1978	2262.6	1052.8	1022.96
21	1979	822.4	-387.4	635.56
22	1980	1095.2	-114.6	520.96
23	1981	682.5	-527.3	6.34
24	1982	810.5	-399.3	405.64
25	1983	1454.6	244.8	160.84
26	1984	1074.8	-135	295.84
27	1985	955	-254.8	550.64
28	1986	895.4	-314.4	865.04
29	1987	497.7	-712.1	1577.14
30	1988	1566.1	356.3	1220.84
31	1989	1215	5.2	1215.64
32	1990	1084.5	-125.3	1340.94
33	1991	612.2	-597.6	1938.54
34	1992	1131.9	-77.9	2016.44
35	1993	1429.7	219.9	1796.54
36	1994	1107.88	-101.92	1897.74
37	1995	1309	99.2	1798.54
38	1996	4357.5	3147.7	1349.16
39	1997	1242.5	32.7	1381.86
40	1998	1116.5	-93.3	1288.56
41	1999	1154	-55.8	1232.76
42	2000	776	-433.8	798.96
43	2001	1030.5	-179.3	619.66
44	2002	1022.5	-187.3	432.36
45	2003	858.7	-351.1	81.26
46	2004	1608	398.2	479.46
47	2005	1439.5	229.7	709.16
48	2006	827.5	-382.3	326.86
49	2007	965.1	-244.7	82.16
50	2008	1129.2	-80.6	1.66
Total		60490.84	0.84	
Average		1209.8		

TABLE 4

Computed average monthly and seasonal rainfall of Saharanpur region

Season	Months	Mean monthly rainfall (mm)	Average seasonal rainfall (mm)
Monsoon	July	349.35	222.745
	August	366.66	
	September	138.15	
	October	36.82	
Winter	November	16.87	38.947
	December	52.31	
	January	42.8	
	February	43.81	
Summer	March	31	57.5
	April	21.38	
	May	33.11	
	June	144.51	
Total		1276.77	

departure of rainfall from the average annual rainfall determines the rainfall pattern. The determination of cumulative departure of rainfall provides the information regarding the total departure of rainfall from the mean value over a specific period. 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 includes mean, median, mode, dispersion, standard deviation, and coefficient of variation. Based on time series analysis (Croxten *et al*., 1988), the prediction of future rainfall trend has been visualized.

3. Mathematical method

The mathematical method is most commonly used, which involves calculation of the average rainfall of years or months as shown by the arithmetic mean of the period of years or months. 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 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.

The total monthly and seasonal rainfall data of Saharanpur have been recorded (Table 4). The trend of monthly rainfall record for a period of 50 years has been exhibited (Fig. 1), whereas the monsoon seasonal variations have been demonstrated to observe the nature of rainfall fluctuation pattern (Fig. 4). The maximum precipitation in last fifty years was recorded as 4357.5 mm during the year of 1996 and minimum rainfall of 497.70 mm was noted in the year of 1987. The average rainfall of the study area has been calculated to be 1209.8 mm. The departure and cumulative departure from the average rainfall of the study areas has been displayed (Table 3, Figs. 3 and 4).

The trend of annual departure from the computed value of average annual rainfall (Table 3, Figs. 3 and 4) reveals that years showing annual departure more than the average annual rainfall were - 1959, 1961, 1964, 1966, 1968, 1971, 1973, 1975, 1976, 1977, 1978, 1983, 1988, 1989, 1993, 1995, 1996, 1997, 2004 and 2005. Years showing annual departure less than the average annual rainfall were - 1960, 1962, 1963, 1965, 1967, 1969, 1970, 1972, 1974, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1990, 1991, 1992, 1994, 1998, 1999, 2000, 2001, 2002, 2003, 2006, 2007 and 2008.

4. Statistical method

The statistical method employed for the analysis of rainfall data of study area for the period from 1959 to 2008, includes determinations of central tendencies (mean, median and mode), skewness, dispersion, kurtosis and time series analysis (Table 5). The procedure of determination of statistical parameters is described below.

5. 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 trend. This analysis is used as a tool to forecast

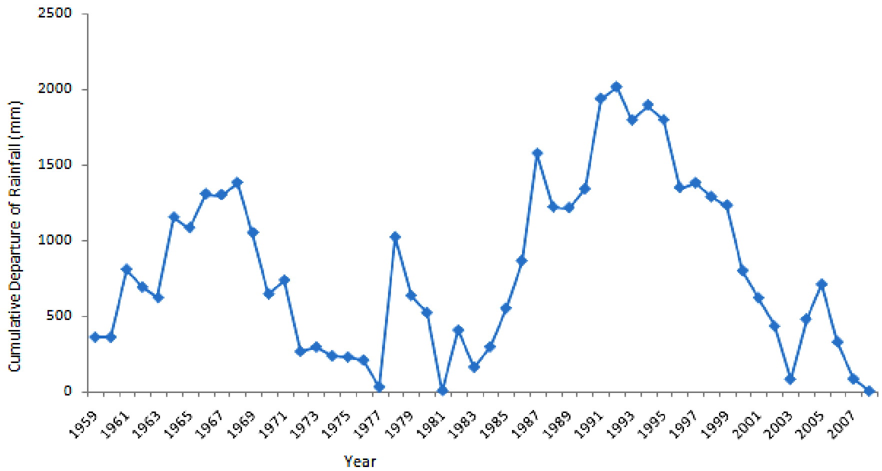

Fig. 3. Cumulative departure of average rainfall (mm) of Saharanpur region

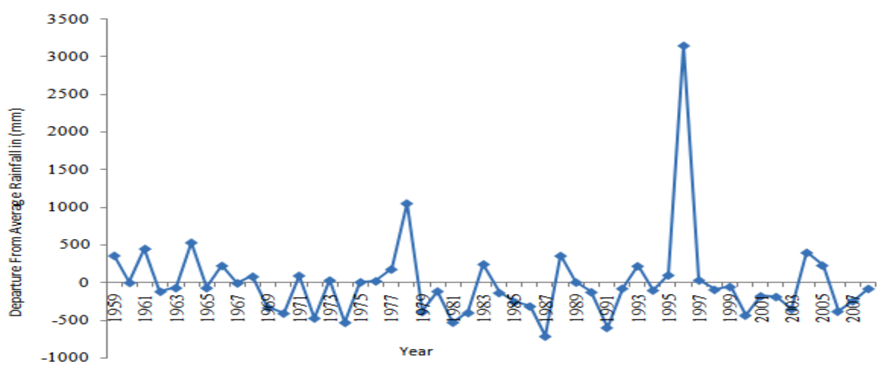

Fig. 4. Departure from average rainfall (mm.) of Saharanpur region

TABLE 5

Statistical parameter determination of rainfall of Saharanpur region

Class interval	Mid value (*x*)	Frequency (*f*)	*fx*	*d* = *x*-1100/200	*fd*	*fd*²	*d*²	Cumulative frequency
400-600	500	1	500	-3	-3	9	9	1
600-800	700	5	3500	-2	-10	20	4	6
800-1000	900	9	8100	-1	-9	9	1	15
1000-1200	1100	13	14300	0	0	0	0	28
1200-1400	1300	11	14300	1	11	11	1	39
1400-1600	1500	6	9000	2	12	24	4	45
1600-1800	1700	5	8500	3	15	45	9	50
Total	7700	$\sum f = 50$	$\sum fx = 58200$	$\sum d = 0$	$\sum fd = +16$	$\sum fd^2 = +118$	$\sum d^2 = 28$	

TABLE 6

Computation of statistical parameters of rainfall data of the Saharanpur

Statistical parameter	Formula	Computed value
Mean	$\bar{x} = \frac{\sum x}{N}$	1164 mm
Median	$i + i/f\,(N/2\text{-C})$	1153.8 mm
Mode	$i + [i\,(f_1\text{-}f_0)] / [2f_1\text{-}f_0\text{-}f_2]$	1066.67 mm
Standard Deviation	$\sigma = 200\sqrt{1/N\sum fd^2 - \left(1/N\sum fd\right)^2}$	300
Coefficient of Dispersion	Standard Deviation/ Mean	0.2577
Coefficient of Variation	100 × (Standard Deviation / mean)	25.773
Coefficient of Skewness	(mean-mode) / Standard deviation	0.3244

the future behavior of the trend. The method of least square fit of straight line has been used for performing the trend analysis of the behavior of annual rainfall. The straight-line equation can be represented as

Where y_c = a + bc

y_c = Trend value of dependent variable

x = Independent variable

a and b = unknown

To establish a best fit straight line the values of a and b must be determined from the observed data. Simultaneous solving of two normal equations does this.

$$\sum y = Na + b\sum x \quad (1)$$

$$\sum xy = a\sum x + b\sum x^2 \quad (2)$$

The values of the various elements in the above equations have been determined by considering y as variable (annual rainfall) and x as constant (year). The determinations were made as per the procedure described below.

$$N = 50 \qquad \sum x = 0 \qquad \sum y = 58917.24$$

$$\sum x^2 = 9800 \qquad \sum xy = 108400.24$$

Substituting these valued in normal equation (1) & (2), two equations (3) & (4) in terms of a and b are developed

$$58917.24 = 50\text{ a} + 0 \quad (3)$$

$$108400.24 = 0 + \text{b } 9800 \quad (4)$$

Solving equations (3) & (4) the values of a & b are obtained as 1178.34 and 11.06 respectively. Hence a equation of straight line is developed, which can be written as

$$\text{i/c} = 1178.34 + 11.06x \quad (5)$$

With the help of equation (5) the trend values have been calculated (Table 7). The future forecast of rainfall amount for period of ten years from 2009 to 2018 has been made.

6. Interpretation of rain fall data

The average rainfall of the Saharanpur area has been calculated and found to be 1276.77 mm. The departure and cumulative departure from the average rainfall of the area under investigation is given in Table 3. The graph (Fig. 4) showing the departure from average rainfall shows that during the year of 1959, 1961, 1964, 1966, 1968, 1971, 1973, 1975, 1976, 1977, 1978, 1983, 1988, 1989, 1993, 1995, 1996, 1997, 2004 and 2005. The rainfall was more than the average. Hence, these years were favorable for groundwater recharge. The graph showing cumulative departure from average rainfall (Fig. 3) reveals that the maximum peak occurred during

TABLE 7

Determination of expected future trend of rainfall in Saharanpur

S. No.	Year	Procedure of determinates	Expected future trend
1.	2009	1202.392 + 11.061(25)	1478.917 mm
2.	2010	1202.392 + 11.061(26)	1489.978 mm
3.	2011	1202.392 + 11.061(27)	1501.039 mm
4.	2012	1202.392 + 11.061(28)	1512.10 mm
5.	2013	1202.392 + 11.061(29)	1523.161 mm
6.	2014	1202.392 + 11.061(30)	1534.222 mm
7.	2015	1202.392 + 11.061(31)	1545.283 mm
8.	2016	1202.392 + 11.061(32)	1556.344 mm
9.	2017	1202.392 + 11.061(33)	1567.405 mm
10.	2018	1202.392 + 11.061(34)	1578.466 mm

the years of 1960, 1962, 1963, 1965, 1967, 1969, 1970, 1972, 1974, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1990, 1991, 1992, 1994, 1998, 1999, 2000, 2001, 2002, 2003, 2006, 2007 and 2008.

These peaks are indicative of maximum rainfall during the corresponding periods and point out sufficient infiltration of water due to maximum rainfall. Statistical analysis of the present rainfall data reveals that the mean rainfall of the area is 1164 mm. The computed value of mode 1066.67 mm indicates ideal rainfall for the area. The calculated value of Standard Deviation reveals that deviation of rainfall is of 300 mm over a period of fifty years. The coefficient of variation indicates that the amount of rainfall varies up to 25.773. The coefficient of Skewness has been noted as 0.3244, which indicates negative trend.

7. Environmental impacts of rainfall factor

Environment Impact Assessment (EIA) is concerned with the analysis of any possible alteration of environmental conditions, adverse or beneficial caused introduced by the action or set of actions under consideration. EIA is multifaceted human oriented and essentially seeks to know what will be the consequences of economic decisions for those human aspects and social development that depend on the economic, and the quality of human interaction with the natural and anthropogenic physical environment (Royston, 1978). 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 variation analysis of rainfall data of Saharanpur region reveals a fairly good range of variation indicating the positive trend before 2000 and negative trend from 2000 onwards that is resulting into depletion of ground water levels. The present trend of over exploitation due to population growth, industrialization, irrigation and lesser rainfall than the annual average value are affecting the recharge of ground water levels, which are depleting at an alarming rate. The depletion of ground water levels may be assigned to seasonal variations in the static ground water levels, which are influenced by infiltration of rainwater and extraction of ground water (Singh, 2009). The implementation of an appropriate strategy for rainwater harvesting will generate the possibilities of increase in the amount and intensities of rainfall that in turn, will improve the augmentation phenomena of ground water reservoir. The control over depleting trend of ground water level will provide remedy of sustained water supply to the inhabitants of Saharanpur region.

8. Conclusion

The rainfall data analysis of Saharanpur region for a period of 50 years from 1959 to 2008 reveals variation in the amount and frequency and points out a negative trend of rainfall in future as well. It is suggested that the optimum development of rainwater harvesting will provide remedial solution to the prevailing problem of shortage of water supply in Saharanpur region. The augmentation of ground water reservoir by increasing the rainwater harvesting, implementation of scheme for a forestation and conservation of rainwater by construction of artificial structures would help to cater the demand of water supply.

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