Environmental Impact of Rainfall Factor on Groundwater System of Manasa area, Neemuch District, Madhya Pradesh, India

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Abstract:

An account of the rainfall data analysis for a period of 25 years to visualize the environmental impacts on groundwater system of Manasa area located in Ratam River Basin of Neemuch district, Madhya Pradesh in Indian sub-continent has been elaborated. obtainable. The Mathematical analysis of rainfall data indicates a fairly good range from 457 mm to 1599.mm with an average of 993.8 mm. The annual departure with respect to average value indicates the nature of positive and negative recharge trend of groundwater reservoir. The cumulative departure indicates trend of increase or decrease in the rain water to groundwater system. The statistical treatment of rainfall data reveals accurate value of Mean = 948 mm, Median = 853.83 mm, Mode = 916.66 mm, Standard Deviation = 1460.41 mm, Co-efficient of dispersion = 1.540 mm, Co-efficient of variation = 64.93, and Co-efficient of skewness = 0.02146. The statistical treatment of rainfall data provide precise values indicating the nature of recharge trend.

Based on time series analysis an attempt has been made to determine the trends of expected future rainfall. The rainfall data analysis infers that more rainfall amount than the average value indicating the period of favorable recharge to groundwater system, whereas, low values than the average value point out the negative trend of recharge that reflect the shortage of water supply, even resulting into drought condition. The rainfall is most important hydrometreological factor that controls the nature of the storage of groundwater system. This rainfall factor is also influencing the environment of society, forest and development of agriculture and vegetation.

Key words:
Environmental impacts; Rainfall factor; Groundwater System; Manasa; Neemuch; Madhya Pradesh; India

Introduction:

Rainfall is a commonly used term for the precipitation and is one of the most vital hydrometeorlogical parameters that influence recharge of the groundwater system. The hydrometeorology is a science, which refers to the study of atmosperric phenomenon and resulting problems associated with water regime. The hydrometerological data are valuable in the determination of the water balance of a basin for developing and managing its water resources. The hydrometerological element's include precipitation (rainfall), evaporation, evapotranspiration, solar radiation (sunshine hours) air temperature, humidity, soil moisture, surface and sub-surface water levels, stream discharge, water quality and others (Todd, 1959, 1980; Raghunath, 1982; Karanth, 2003).

Rainfall infiltration provides most important source of groundwater recharge. In India, most of the recharge takes place during the monsoon period extending from June to September. Recharge during winter and summer interval is rather less or negligible. The rock formations encountered in the upper layers of the earth are generally considered as the basis for dividing the country into various regions for presuming the percentage of rainfall infiltration (Nagabhushaniah, 2001).

The rain phenomena occur in diverse forms such as cloud, dew, fog, frost etc. The liquid form of the precipitation is generally called as the rainfall. The rainfall is measured with the help of rain gauges as unit of mm, cm or inch. The periods of rainfall records may range from the minute, hour, day, month or a year. The rate of rainfall is noted from the computation for a particular day or multiple numbers of days from the records of daily readings of the standard gauge. The environmental impacts of rainfall phenomena on groundwater system of Manasa area located in Neemuch district, Madhya Pradesh, India, have been discussed herein.

Study Area:

The study area of rainfall data analysis, is located in Manasa block, Neemuch district, of Madhya Pradesh,, India, within latitudes from 24^0 18' to 24^0 30' N and longitudes from 75^0 5' to 75^0 15' E (Survey of India toposheet no. 45 P/3, Figure 1). Geologically, Manasa area is occupied by the rocks of Vindhyan Super Group (Pre-Cambrian) and Deccan Traps (Upper Cretaceous to Lower Eocene age).

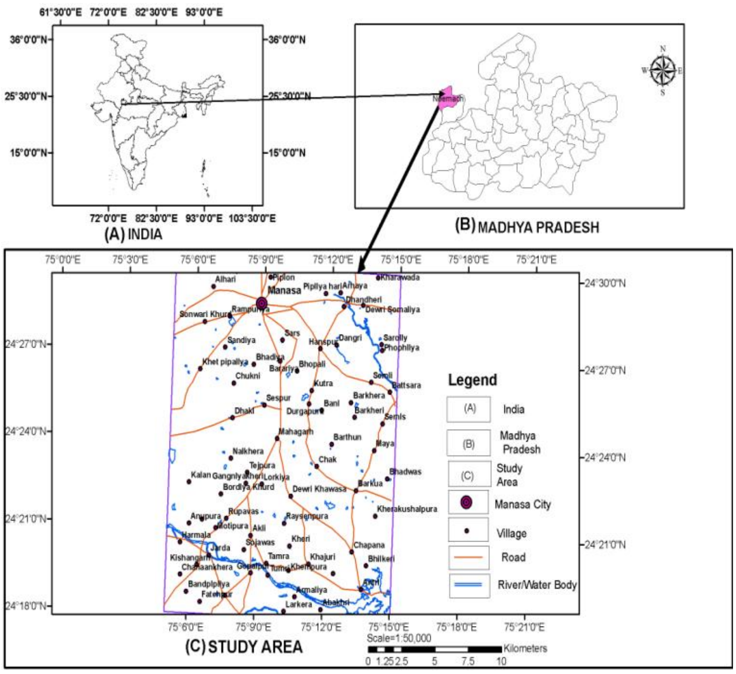

Figure 1 Location map of Manasa study area, Neemuch district, M.P.

Methodology:

The rainfall data are measured by a network or rain gauges mainly of the recording and non-recording types Symons rain gauge is commonly used. The rain water in the gauge is measured in mm daily at a fixed time. The natural siphon recording rain gauge provides continuous record of rainfall, its intensity and duration (Raghunath, 1982). Rainfall data from a number of adjacent stations can be used to determine isohyetal lines or isohyets, which join all points that receive the identical amount of precipitation. An isohyetal map displays the areal distribution of precipitation and forms the basis for the overall prospective water in a particular region.

The rainfall data are considerably variable in a particular region throughout a period. The rainfall data measurements reveal variations in the amount, intensity and distribution from place to place and even in a period of single storm or period of time. The rainfall data are usually subjected to both arithemetic and statistical methods. In the present work, rainfall data of Manasa area, Neemuch district, Madhya Pradesh have been collected for the period of 25 years (1989 to 2013) from the office of Ground Water Survey Unit, Ujjain District. These data have been analysed and results are displayed (Table 1).

Table: 1 Rainfall data from 1989 to 2013 in respect of study area, Neemuch district, (M.P.)

No.	Year	Jan.	Feb.	Mar.	Apr.	May	Jun	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1	1989	-	-	-	-	-	83.5	151.1	468.5	67.5	8.4	-	-	779
2	1990	-	-	-	-	-	152.2	231.2	387.1	175.5	12.7	-	-	958.7
3	1991	-	-	-	-	-	8.1	340.6	398	104.7	-	-	-	851.4
4	1992	-	-	-	-	-	33	464	233	145	106	14	-	995
5	1993	-	7.2	4.5	-	-	207.3	340.1	145.6	103	-	-	-	807.7
6	1994	13	-	-	4	16	209	293.2	342	186	-	-	69	1132.2
7	1995	60	-	9.6	-	-	30	443	149	100	-	-	56	847.6
8	1996	-	-	-	-	-	129	483	509	262	-	-	63	1446
9	1997	-	-	-	-	-	86	251.2	204	123	118	-	-	782.2
10	1998	-	-	-	-	-	85	155	98	258	84	-	248	928
11	1999	-	47.8	-	-	-	39	449	126	122.4	10.6	-	-	794.8
12	2000	-	-	-	-	15	66	403	90	36	-	-	-	610
13	2001	-	-	2	-	40	202	455	193	-	12	-	-	904
14	2002	-	7	-	-	-	121	39	220	70	-	-	-	457
15	2003	-	-	-	-	-	193	191.8	177	166	-	-	-	727.8
16	2004	-	-	-	-	-	80.8	219.1	675.2	-	-	-	-	975.1
17	2005	-	-	-	-	-	113.6	194.4	372.9	231	-	-	-	911.9
18	2006	-	-	9.3	-	30.2	260.8	271.6	1027.8	-	-	-	-	1599.7
19	2007	-	-	-	-	-	40.7	232.2	264.8	47.3	-	-	-	585
20	2008	-	-	-	-	-	167.4	291.3	319	98.4	-	26	-	902.1
21	2009	-	-	-	-	-	18.7	235.5	192.3	40.3	5.00	15	-	506.8
22	2010	-	-	-	-	-	8.7	285.3	279.6	45.5	1.00	-	-	620.1
23	2011						6.7	395.5	459.8	36.2	2.2			900.4
24	2012						9.2	409.3	480.3	32.9				931.7
25	2013						11.5	398.9	512.8	40.3	5.3			968.8
	Total	**73**	**62**	**25.4**	**4**	**101.2**	**2363.1**	**7623.4**	**8324.9**	**2490.7**	**364.9**	**55**	**373**	**21923**
	Avenge.	2.92	2.48	1.01	0.16	4.04	94.52	304.93	332.99	99.62	14.59	2.2	14.92	993.8

Results and Discussion

The results of rainfall data analysis are discussions are recorded in the following text. The mathematical method involves determination of average rainfall for the period of month's or year . The variation in the rainfall is expressed with respect to average. The rainfall data records for a period of 25 years have been displayed (Table 1). The monthly rainfall and the average annual rainfalls have been computed. The average of total annual rainfall has been calculated as 993.8 mm. The total annual rainfall data have also been exhibited by graphic method to illustrate the variation trend (Figure, 2). The graphic representation exhibits a fairly good variation in the amount of annual rainfall. The analysis reveals that the maximum rainfall 1599.7 mm during 2006 and the minimum value of rainfall as 457.mm. during the year of 2002. The average monthly rainfall has been computed for a period of 25 years (1989 to 2013) exhibited by graph and bar diagram (Table-1, Figure 3) indicating trend of monthly rainfall variation. The maximum rainfall of 8324.9 mm observed during the month of August and minimum rainfall value as 4.0 mm during April.

The departure and cumulative departure form the average rainfall have been worked out and the determined value are recorded and exhibited (Table 2, Fig 4; 5). The rainfall pattern indicates that the rainfall during the years of 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1998, 2001, 2004, 2005, 2006 and 2008 have recorded more than the computed value of the average annual rainfall, pointing out the favourable period for the recharge of rain water to the groundwater system, whereas the years of 1989, 1997, 1999, 2000, 2002, 2003, 2007, 2009,2010, 2011, 2012 and 2013 are revealing lower values of annual rainfall than the average annual rainfall, indicating the negative trend of rainwater recharge to the groundwater reservoir.

Table: 2 Annual rainfall departure and cumulative departure from average annual rainfall in Manasa area during period of 1986-2010.

No.	Year	Total Rain - fall (mm.)	Departure from average rainfall (mm.)	Cumulative Departure from average rainfall (mm.)
1	1989	779	-214.8	-214.8
2	1990	958.7	-35.1	-249.9
3	1991	851.4	-142.4	-392.3
4	1992	995	+1.2	-391.1
5	1993	807.7	-186.1	-577.2
6	1994	1132.2	+138.4	-438.8
7	1995	847.6	-146.2	-585
8	1996	1446	+452.2	-132.8
9	1997	782.2	-211.6	-344.4
10	1998	928	-65.8	-410.2
11	1999	794.8	-199	-609.2
12	2000	610	-383.8	-993
13	2001	904	-89.8	-1082.8
14	2002	457	-536.8	-1619.6
15	2003	727.8	-266	-1885.6
16	2004	975.1	-18.7	-1904.3
17	2005	911.9	-81.9	-1986.2
18	2006	1599.7	+605.9	-1380.8
19	2007	585	-408.8	-1789.1
20	2008	902.1	-91.7	-1880.8
21	2009	506.8	-487	-2367.8
22	2010	620.1	-373.7	-2741.5
23	2011	900.4	-93.4	-2834.9
24	2012	931.7	-62.1	-2897
25	2013	968.8	-25	-2922
	Total	21923 mm.		
Average	993.8 mm.			

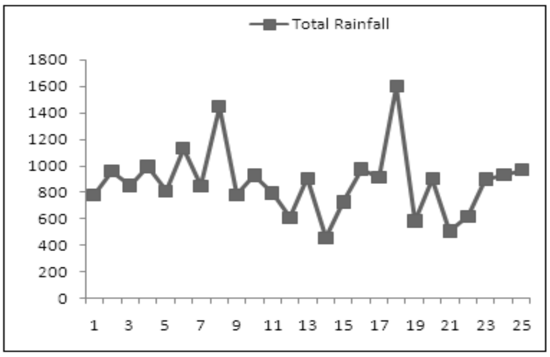

Figure 2 Annual distribution of rainfall data of Manasa area.

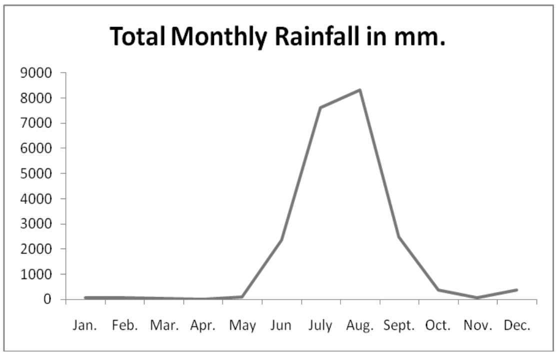

Figure 3 Monthly distribution of rainfall data of Manasa area.

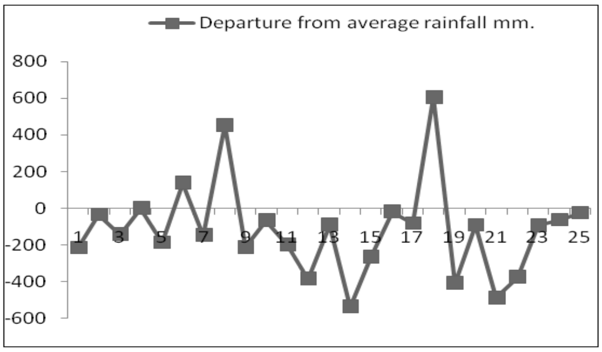

Figure 4 Annual departure from average rainfall data, Manasa area.

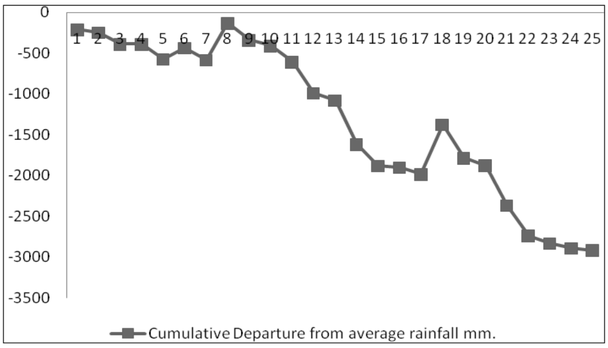

Figure: 5 Annual cumulative departure from average rainfall data, Manasa area.

Statistical method has been employed for the rainfall data analysis of study area for a period from 1989 to 2013. It includes determinations of central tendency (mean, median, and mode), standard deviation, dispersion, variation, skewness, and time series analysis for determination of future rainfall trend. The measure of central tendencies, standard, skewness, dispersion and variation of the rainfall data have been classified in to class intervals. The procedure of statistical analysis have been proposed by several workes namely, Gupta and Kapoor (1977), Devis (1986, 2002), and Croxton (1988). The common procedure of determination of the statistical parameters has been adopted (Table 3).

Table: 3 Statistical parameter determination of rainfall of Manasa area, Neemuch district (M.P.)

Class Interval	Mid value (x)	Frequency	fx	d=x-900/ 200	fd	fd^2	d^2	Cumulative Frequency
400-600	500	3	1500	-2	-6	12	4	3
600-800	700	6	4200	-1	-6	6	1	9
800-1000	900	13	11700	0	0	0	0	22
1000-1200	1100	1	1100	1	1	1	1	23
1200-1400	1300	0	0	2	0	0	4	0
1400-1600	1500	2	3000	3	6	18	9	25
Total	6000	$\sum$ f = N N=25	$\sum$ f = 21500	$\sum$ d= 3	$\sum$ fd = 6	$\sum fd^2$ =37	$\sum d^2$ =19	

Mean: Mean for a set of observation is computed based on the sum of observations divided by the number of observations. It is usually calculated by the following expression variables study area (Table 5.4). Mean = A+ (I x$\sum fd$)/N, Where, A=Assumed mean = 900 mm, I = Class interval = 200mm, F = frequency (fd) =6, N = Total frequency = 25, Mean = 900+ [200 x (6)] / 25, Mean = 948 mm.

Median: For a set of observations, median is the variable which divides into two equal parts. It is determined by the following formula. Median = I+ i/f (N/2-C), Where, I = Lower limit of median class = 800 mm, F = frequency of median class = 13, I = magnitude of median class = 200, C = Cumulative frequency of the class preceding the median class= 2, Median = $\left(\frac{N}{2}=\frac{25}{2}=12.5\right)$,

Median= 800+$\frac{200}{13}$ (12.5-9), Median = 853.83 mm

Mode: It is the determination of value which occurs most frequently in a given set of observations. It is calculated by the following formula- Mode = I + i $(f_1-f_0)/(2f_1 - f_0 - f_2)$, where, I = Lower limit of model class = 800mm, I = Class interval = 200 mm, f_1 = frequency of mode class = 13, f_2 = frequency of class succeeding the mode class = 1, f_0 = frequency of class preceding the mode class = 6, Mode = 800 +200 (13-6)/2 x13-6 -1, Mode = 916.66 mm.

Standard Deviation: Standard deviation usually represented by the Greek latter small sigma (σ) is the positive square root of the arithmetic mean of the squares of the deviation of the given values from their arithmetic mean.

$S.D.(\sigma) = I\sqrt{1/N\ \Sigma fd^2 - (1/N\ (\Sigma fd)^2}$,

Where, σ = Standard Deviation, I =Class interval σf =N = Number of total sample, = $200\sqrt{1/25(37)^2 - 1/25(6)^2}$, = $200\sqrt{53.32}$, Standard Deviation =1460.41 mm.

Co-efficient of Dispersion: Whenever we want to compare the variability of the two series which are dispersion but we calculate the co-efficient of dispersion which are pure numbers independent of the units of measurement.

Co-efficient of dispersion = Standard deviation/mean, In the study area, S.D. = 1460.41, mean = 948., Co-efficient of dispersion = Standard deviation/ mean, = $\frac{1460.41}{948}$, Co-efficient of dispersion = 1.540 mm

Co-efficient of Variation: The 100 times of co-efficient of dispersion based upon standard deviation is called coefficient of variation (C.V.), C.V. = 100 x (standard deviation/mean), In the study area, S.D. = 1460.41,Mean = 948, = 100 x (1460.41/948), Co-efficient of variation = 64.93.

Co-efficient of skewness: The lack of symmetry we study skewness to have an idea about the shape of the curve which we can draw with the help of the given data.

Co-efficient of skewness = $\frac{(mean - mode)}{standard\ deviation}$, I n the study area, mean = 948, mode = 916.66,

S.D. = 1460.41, S_k = 948-916.66/1460.41, Co-efficient of skewness = 0.02146.

Time Series Analysis:

Time series analysis provides significant informations regarding the trend of a series of observation, It helps 1. To measure the deviation from the trend and 2. provides an information on the nature of trend. Hence, this analysis enables us to forecast the future behavior of trend (Gupta and Kapoor, 1977).

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 = a + bx+cx2

y = Trend value of dependent variable

x = Independent variable

a, b and c = unknown

Table: 4 Time series Analysis of rainfall data of the study area.

No.	Year	X	Y	x^2	Xy	x^3	x^2y	x^4
1	1989	-12	779	144	-9348	-1728	112176	20736
2	1990	-11	958.7	121	-10545.7	-1331	116002.7	14641
3	1991	-10	851.4	100	-8514	-1000	85140	10000
4	1992	-9	995	81	-8955	-729	80595	6961
5	1993	-8	807.7	64	-6461.6	-512	51692.8	4096
6	1994	-7	1132.2	49	-7925.4	-343	55477.8	2401
7	1995	-6	847.6	36	-5085.6	-216	30513.6	1296
8	1996	-5	1446	25	-7230	-125	36150	625
9	1997	-4	782.2	16	-3128.8	-64	12515.2	256
10	1998	-3	928	9	-2784	-27	8352	81
11	1999	-2	794.8	4	-1589.6	-8	3179.2	16
12	2000	-1	610	1	-610	-1	610	1
13	2001	0	904	0	0	0	0	0
14	2002	1	457	1	457	1	457	1
15	2003	2	727.8	4	1455.6	8	2911.2	16
16	2004	3	975.1	9	2925.3	27	8775.9	81
17	2005	4	911.9	16	3647.6	64	14590.4	256
18	2006	5	1599.7	28	7998.5	125	39992.5	625
19	2007	6	585	36	3510	216	21060	1296
20	2008	7	902.1	49	6314.7	343	44202.9	2401
21	2009	8	506.8	64	4054.7	512	32435.2	4096
22	2010	9	620.1	81	5580.9	729	50228.1	6961
23	2011	10	900.4	100	9004	1000	90040	10000
24	2012	11	931.7	121	10248.7	1331	11275.7	14641
25	2013	12	968.8	144	11625.6	1728	139507.2	20736
	Total	Σx=0	Σy = 21923 mm	ΣX^2 =1300	Σxy = - 5355.4	Σx^3 =0	Σx^2y = 1149337.4	Σx^4 = 4122220

The value of a, b and c must be determined from the observed data this is done by solving of two normal equation.

$\Sigma y = Na + b\Sigma x + c\Sigma x^2$ ....(A)

$\Sigma xy = a\Sigma x + b\Sigma x^2 + c\Sigma x^3$ ....(B)

$\Sigma x^2y = a\Sigma x^2 + b\Sigma x^3 + c\Sigma x^4$ ....(C)

The values of the different elements in the above equation have been determined by considering y as variable (annual rainfall) and x as constant (year).

The determination are made as per the following procedure (Table 4)-

$N = 25$, $\Sigma x = 0$, $\Sigma y = 21923$, $\Sigma x^2 = 1300$, $\Sigma xy = -5355.4$, $\Sigma x^3 = 0$, $\Sigma x^2y = 1149337.4$, $\Sigma x^4 = 4122220$

Substituting these values in normal equation A ,Band C three equation interim of a, b and c are developed-

21923= 25 (a) + (1300) c .... (D)

-5355.4= (1300) b ….................. (E)

1149337.4= (1300) a +4122220 c ...... (F)

a =779.15, b = -4.28, c = 1.60

Solving equations (D),(E) and (F) the value of a, b & c are obtained as 876.80, - 4.12 and 0.0023respectively

$y = 876.80 +(- 4.12) x + 0.0023(x^2)$ ....(G)

The help of equation (G) the trend values have been calculated. The future fore cost of rainfall amount for period of five years 2014 to 2018 has been made the procedure is below (Table 5)

Table: 5 Procedure of determination of expected future trend of rainfall in the Manasa study area.

S. No.	Year	Procedure of determination	Expected future rainfall
1	2014	$876.80+ (-4.12)13+0.0023(13)^2$	±823.63 mm
2	2015	$876.80+ (-4.12)14+0.0023(14)^2$	±819.57 mm
3	2016	$876.80+ (-4.12)15+0.0023(15)^2$	±815.52 mm
4	2017	$876.80+ (-4.12)16+0.0023(16)^2$	± 811.47mm
5	2018	$876.80+ (-4.12)17+0.0023(17)^2$	±807.43mm

Environmental Impact of Rainfall:

The rainfall pattern plays a vital role in the recharge phenomena of groundwater system, besides other environmental impacts. The rainfall data analysis of Manasa area, Neemuch district, indicates a fairly good range of variation pointing out the positive as well as negative trends that is effect the recharge of the groundwater reservoir. The present trend of over exploitation and scanty rainfall is causing depletion in the groundwater level. Todd, (1980) described that the groundwater levels may reflect seasonal variation due to rainfall. Drought extending over a period of several years, contribute to declining water levels. The depletion of groundwater levels may be assigned to seasonal variation in the static groundwater levels, which are controlled by infiltration of rainwater. This process is dependent on the rainfall amount and intensity.

It is suggested that the groundwater recharge phenomena can be better by augmentation of rain water. The implementation of a suitable measure may likely to provide remedy in managing the rapidly developing situation of groundwater level depletion resulting in the drought condition in Manasa study area.

Conclution:

Rainfall is an important hydrometeorological factor that plays an imperative role in environmental entity as a major source for the recharge of groundwater system. The rainfall data analysis of 25 years from 1989 to 2013 has been carried out by following both mathematical and statistical techniques.

The mathematical analysis determines annual average value of rainfall as 993.8 mm. The rainfall pattern indicates that the rainfall during the years of 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1998, 2001, 2004, 2005, 2006 and 2008 have recorded more than the computed value of average annual rainfall, pointing out the favorable period for the recharge of rain water to groundwater system, whereas the years of 1989, 1997, 1999, 2000, 2002, 2003, 2007, 2009, 2010, 2011, 2012 and 2013 revealing lower values of annual rainfall than the average annual rainfall, indicating a negative trend of rainwater recharge to the groundwater reservoir.

The statistical analysis has been computed for determination of mean (948 mm), median (853.83 mm), mode (916.66 mm), standard deviation (1460.41), co-efficient of dispersion (1.540), co-efficient of variation (64.93) and skewness (0.02146). The time series analysis of the rainfall data has been conducted for the approximation of future rainfall trend for the next ten years that indicates negative trend of recharge. The environmental impacts of rainfall factor in recharge phenomena of groundwater system have been discussed.

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