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Analysis of rainfall factor and environmental implications on recharge of groundwater system of Katthiwada area, Alirajpur District, Madhya Pradesh, India

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Abstract
The paper deals with the results of rainfall data analysis for a period of 31 years (1985 to 2015) in respect of Katthiwada area located in Alirajpur district, Madhya Pradesh, India, with a prime objective to envisage the environmental impacts on the groundwater system of Katthiwada. The rainfall data have been treated to both the mathematical and statistical techniques. The mathematical analysis of rainfall data reflects a fairly good range from 307.2 mm to 1562.3 mm with an average of 835.27 mm. The annual departure with respect to the average value exhibits the nature of positive and negative recharge trends of groundwater system. The cumulative departure indicates trend of decrease and increase in the rainwater to the groundwater system. The statistical analysis of rainfall data reveals accurate value of Mean = 862.85 mm, Median = 884.84 mm, Mode = 950 mm, Standard Deviation = 281.51, Co-efficient of dispersion = 0.326 mm, Co-efficient of variation = 32.62 and Co-efficient of skewness = (-) 0. 30. The statistical treatment of rainfall data affords precise values of recharge trend.
The time series analysis of rainfall data enables the delineation of the trends of expected future annual rainfall. The rainfall data analysis points out that higher rainfall values than the average value indicate the period of favourable recharge to groundwater system, whereas, lower values than the average value point out the negative trend of recharge that reflect the shortage of water supply. The future rainfall trend for the five years has been determined as more than the average annual rainfall indicating a positive trend. The rainfall is one of the important hydrometreological factors, which controls the recharge phenomena of the groundwater system. This rainfall factor is also influencing the environment of the society, forest and development of agriculture and vegetation.

Keywords: Rainfall factor, Environmental implication, Groundwater System, Recharge, Katthiwada Madhya Pradesh, India

Introduction
Rainfall is the general term of Precipitation. The rainfall occurs in different forms such as solid, liquid and gas. The liquid form of precipitation is commonly known as the rainfall. According to Wiesner (1970) the term precipitation has been defined as "The depositing of water from the atmosphere on to the surface. This deposit may be either liquid or solid to give the various forms of precipitation" Navarra (1979) described that the rainfall is usually related with "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". Hence, the rainfall is one of the most significant meteorological parameters, which plays a crucial role in the recharge of groundwater system. It acts as an important factor in the evaluation of the water balance of a basin.
The rainfall is measured by means of the rain gauges. The recorded values of rainfall are expressed in inch or mm. The rainfall records reveal a wide range of variation in the amounts and frequencies from place to place. The duration, amount and frequency of rainfall help in acceleration of the scope of surface runoff for groundwater recharge. In India, rainfall mostly occurs during the monsoon period (June to September). Dhar and Rakchha (1975) have published a review of the hydro-meteorological studies of Indian rainfall. This paper deals with the rainfall data analysis and interpretation of analyzed data and a discussion on the environmental role on the recharge of groundwater system of Katthiwada area of Alirajpur district of Madhya Pradesh.

Study Area
The present study area located in Katthiwada (latitude 22 °25'to 22°30 N and longitude 74°5' to 74°15' E) in Alirajpur district ,Madhya Pradesh (Survey of India Toposheet No 46 J/3). Physiographically, Katthiwada area is characterized by the hilly region revealing a typical undulating topography with plain area. The temperature ranges from 10° C to 50°C. The climate of the area is typical monsoon type. The area is approachable by the road throughout the year.

Geology of study area
The regional geological setting of Katthiwada study area comprises rocks of the Arravali group, Lameta and Bagh Beds, Deccan Traps, Alluvium and laterite. Katthiwada area is characterized by the presence of Arravali group (Phyllites, Quartzes, Granites, Amphibolites, Dolomite, lime stone, volcanic lava flows, and intrusion of dolerite).

Materials and methods
The rainfall records of Katthiwada area of Alirajpur district, Madhya Pradesh for a period of 31 years (1985 to 2015) have been collected from District Collectorate Office, Alirajpur, and analyzed by using both the mathematical and statistical methods. The procedure of analysis is described herein.

Mathematical Analysis

The mathematics analysis is the most widely used method for rainfall data this method involves calculation of the average for the period of specific months or years as mathematics average. The calculated values are expressed in mm. The variation in rainfall is indicated by a mathematical mean. The mathematics analysis of rainfall data indicates the average annual rainfall as 835.277 mm. The annual rainfall data exceededing the computed average value have been observed during the years of 1990, 1993,1994, 1996, 1997, 1998, 2003,2004, 2006, 2007, 2013, 2014, 2015 indicating rather favourable periods for groundwater recharge.

Table 1: Annual Rainfall, Departure and Cumulative From the Annual Average in Alirajpur District (M.P.)

S. No.	Years	Total Rainfall (mm)	Departure from Average Rainfall	Cumulative Departure from Average Rainfall
1.	1985	307.2	-528.07	528.07
2.	1986	512	-323.27	-851.35
3.	1987	764.4	-70.87	-922.21
4.	1988	787.2	-48.07	-970.28
5..	1989	701.4	-133.87	-1104.15
6.	1990	1229.8	394.52	-709.63
7.	1991	712	-123.27	-832.9
8.	1992	696	-139.27	-972.17
9.	1993	1068.8	233.52	-738.65
10.	1994	1360	524.72	-213.93
11.	1995	724	-111.27	-325.2
12	1996	1096	260.72	-64.48
13	1997	942.4	107.12	42.64
14	1998	995.4	160.12	202.76
15	1999	532.5	-302.77	-100.01
16	2000	392.4	-442.87	-542.88
17	2001	549.2	-286.07	-828.95
18.	2002	738.4	-96.87	-925.82
19.	2003	1101	265.72	-660.1
20.	2004	1265.4	430.12	-229.98
21.	2005	678.9	-156.37	-386.35
22.	2006	1562.3	727.02	340.67
23.	2007	1037.4	202.12	542.79
24.	2008	624.2	-211.07	331.72
25.	2009	557.2	-278.07	53.65
26.	2010	611	-224.27	-170.62
27.	2011	584.7	-250.5	-421.12
28.	2012	803	-32.27	-453.39
29.	2013	1232.8	397.52	-55.87
30	2014	851	15.72	-40.15
31	2015	875.6	40.32	0.17
	Total	25893.6		
	Average	835.277		

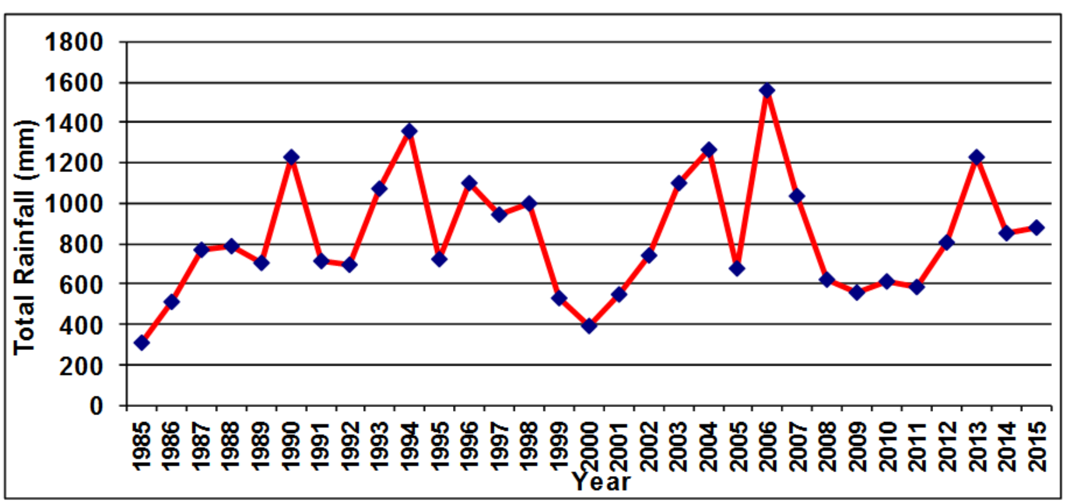

Fig 1: Total annual rainfall of Alirajpur district M.P for the period 1985 to 2015

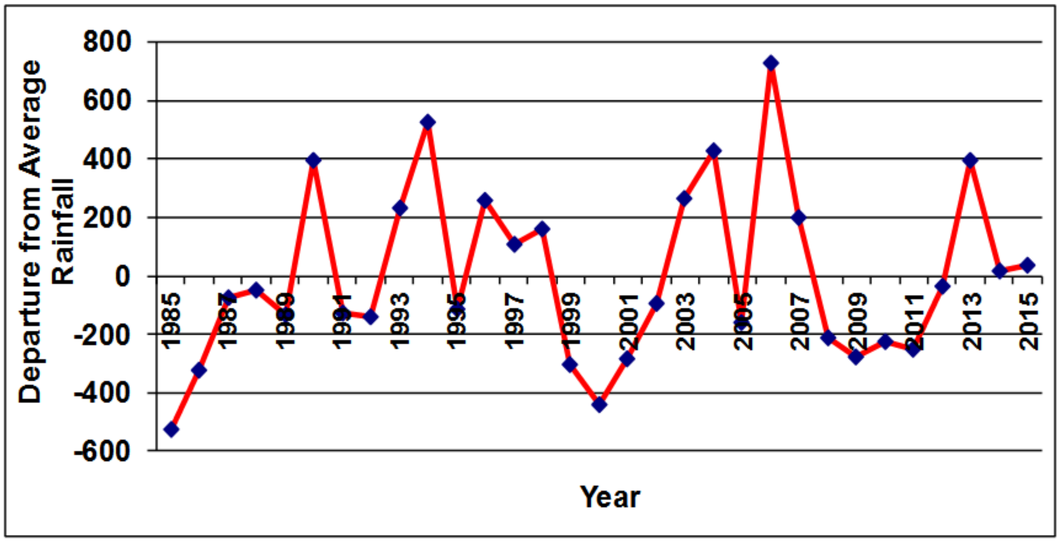

Fig 2: Departure from average rainfall in Alirajpur district M.P. for the period of 1985 to 2015.

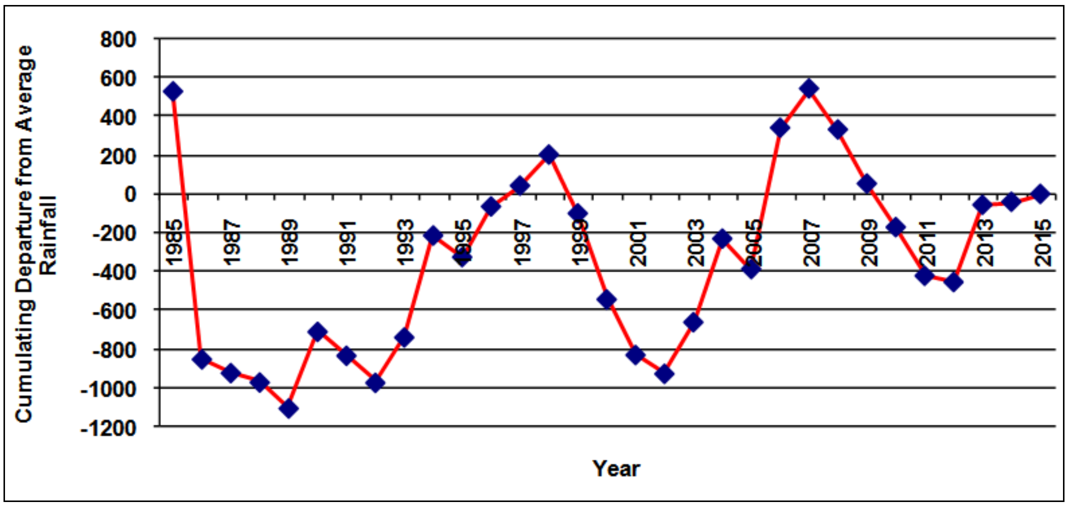

Fig 3: Cumulative departure from average rainfall of Alirajpur district M.P. for the period of 1985 to 2015

Statistical Analysis

The statistical method includes determinations of central tendencies (mean, medium, and mode), standard deviation, skewness, dispersion and time series analysis. The rainfall data of Alirajpur district area have been classified into seven groups table 2 and various statistical parameters were computed and described. The method of statistical analysis suggested by Gupta and Kapoor (1977), Davis (1986, 2002); and Croxton *et al.* (1988) have been adopted herein.

Table 2: Statistical analysis of rainfall data of Katthiwada area in Alirajpur district showing frequency distribution.

S. No.	Class Interval	Mid Value	Frequency (f)	Fx	dx=(x-a)/q	fμ	μ^2	$f\mu^2$	c.f.
1.	300-500	400	2	800	-3	-6	9	18	2
2.	500-700	600	9	5.400	-2	-18	4	36	11
3.	700-900	800	9	7.200	-1	-9	1	9	20
4.	900-1100	1000	5	5000	0	0	0	0	25
5.	1100-1300	1200	4	4800	1	4	1	4	29
6.	1300-1500	1400	1	1.400	2	2	4	4	30
7.	1500-1700	1600	1	1.600	3	3	9	9	31
	Total	7000	31	$\sum fx_{=26.200}$	$\sum \mu_{=0}$	$\sum f\mu_{=-24}$	28	80	

Mean

Mean for a set observation, is their sum divided by the number of observations, it is calculated by the following formula:

Mean = A + (i x $\sum f\mu$)/N

Where,

A = Assumed Mean = 1000
i = Class interval = 200
f = Frequency = -24
N = Total Frequency = 31

Mean = 1000 + [200 (-24)]/35
= 1000 - 160
= 862.85

Median

Median is defined as the variable which divides a set of observation into two equal parts. It is determined by the following formula:

Median = 1 + i + f (N/2 - C)

Where,

1 = Lower limit of medium class = 9
F = Frequency of medium class = 5
I = Magnitude of Median Class = 20
C = Cummulative frequency of the medium class preceding the median class = 20.

Median = 900 + 200/2 (15.20)
Median = 884.84.

Mode

Mode is the value which occurs most frequently in a given set of observation and it is calculated by the use of given formula:

Mode = 1 + [i(f1 - f0)] / [2f1 - f0 - f2

Where,

1 = Lower limit of model class = 900.
i = Class interval = 200
f1 = Frequency of model class = 5
f0 = Frequency of class preceding the model class = 9
f2 = Frequency of Class succeeding the model class = 4.

Mode = 900 + [200 (5-9)] / [2 * 5-(9-4)]
= 900 + [200 (-4)] / [-16]
= 900 + 50
= 950

The rainfall data analysis of katthiwada area has been carried out by mathematical and statistical techniques. The mathematical analysis indicates average annual value of rainfall as (835.27 mm) and trend of recharge variation of ground water system. The statistical analysis reveals that mean (862.85 mm), median (884.84 mm), and mode (950 mm), of rainfall data interpret the impact on the recharge of ground water system.

Standard Deviation

Standard deviation is a measure of the positive square root of the arithmetic mean of squares of the deviation of given values from their arithmetic mean.
It is computed by the use of the following expression.

S.D. $\sigma = i / N\sqrt{Nf\mu^2 - (\sum f\mu)^2}$

Where,

σ = Standard deviation
N = Total frequency = 31
i = Class interval = 200

= 80, = -24
= 200$^{1/31}$ $\sqrt{31\ x\ 80 - (-24)^2}$
= 200/31 $\sqrt{1904}$
= 281.51

Co-Efficient of dispersion

It is the measure of scatteredness and is calculated by following formula:

CD = Standard Deviation / Mean

Where;

Standard Deviation = -281.51
Mean = 862.85

Co-efficient of Dispersion (CD) = 281.51 / 862.85
= 0.326

Co-efficient of variation

Co-efficient of variation has been defined as the percentage variation in the mean standard deviation being considered as the total variation in the mean. It is calculated by the given formula:

Co-efficient of variation = 100 x (Standard Deviation) / Mean
Mean = 862.85
Standard Deviation (SD) = 281.51
= 32.62

Co-Efficient of skewness

It denotes luck of symmetry in the given distribution and is computed by using the formula:

Co-efficient of Skewness = (Mean - Mode)/Standard Deviation
Mean = 862.85
Mode = 950
Standard Deviation = 281.51
Co-efficient of Skewness = (862.85 - 950)/281.51
= -0.30

Time series analysis

The time series analysis generates valuable information and regarding the trend of a observation. 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 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,

Yc = a + by
Yc = 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. This is done by simultaneous solving of two normal equations.

Table 3: Time series analysis of Rainfall Data of Katthiwada Area, Alirajpur District, Madhya Pradesh.

Year	(x)	Rainfall (y) mm	(x^2)	xy	Trend value
1985	-15	307.2	225	-4608	765.52
1986	-14	512	196	-7168	770.17
1987	-13	764.4	169	-9937.2	774.82
1988	-12	787.2	144	-9446.4	779.7
1989	-11	701.4	121	-7715.4	784.12
1990	-10	1229.8	100	-12298	788.77
1991	-09	712	81	-6408	793.42
1992	-08	696	64	-5568	798.07
1993	-07	1068.8	49	-7481.6	802.72
1994	-06	1360	36	-8160	807.37
1995	-05	724	25	-3620	812.02
1996	-04	1096	16	-4384	816.67
1997	-03	942.4	9	-2827.2	821.32
1998	-02	995.4	4	-1990.8	825.97
1999	-01	532.5	1	-532.5	830.62
2000	00	392.4	0	0	835.27
2001	+1	549.2	1	549.2	839.92
2002	+2	738.4	4	1476.8	844.57
2003	+3	1101	9	3303	849.22
2004	+4	1265.4	16	5061.6	853.87
2005	+5	678.9	25	3394.5	858.52
2006	+6	1562.3	36	9373.8	863.17
2007	+7	1037.4	49	7261.8	867.82
2008	+8	624.2	64	4993.6	872.47
2009	+9	557.2	81	5014.8	877.12
2010	+10	611	100	6110	881.77
2011	+11	584.7	121	6431.7	886.42
2012	+12	803	144	9636	891.07
2013	+13	1232.8	169	16026.4	895.72
2014	+14	851	196	11914	900.37
2015	+15	875.6	225	13134	905.02
		Y=25893.6	2480	11536.1	

$$\sum y = N\mu + b\sum y \quad \text{.... (1)}$$

$$\sum xy = a\sum X + b\sum x^2 \quad \text{.... (2)}$$

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

$$N = 31, \sum x = 0, \sum y = 25893.6$$

$$\sum x^2 = 2480, \sum xy = 11536.1$$

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

25893.6 = 31(a) + 0 (b) .... (3)
11536.1 = 0 (a) + 2480 (b) .....(4)

Solving equations (3) and (4) the value of (a) and (b) are obtained as 835.27 and 4.65 respectively.
Hence an equation of straight line developed, which can be written as

Yc = 835.27 + 4.65 x .....(5)

With the help of equation (5) the trend values have computed in table. The future forecast of rainfall amount for a period of five years - 2016 to 2020 has been made as per the procedure listed below:

Y2016 = 835.27 + 4.65 x 16 = 909.67
Y2017 = 835.27 + 4.65 x 17 = 914.34
Y2018 = 835.27 + 4.65 x 18 = 918.97
Y2019 = 835.27 + 4.65 x 19 = 923.62
Y2020 = 835.27 + 4.65 x 20 = 928.27

Based on Time series analysis of data, the forecast of expected annual rainfall for a period of 2020, has been attempted. The relationship between parameters such as rainfall- runoff recharge have been observed. The calculated trend values of rainfall for the coming years.

Year	Expected Rainfall (mm.)
2016	909.67
2017	914.34
2018	918.97
2019	923.62
2020	928.27

Environmental Impacts

The rainfall factor plays a key function in the recharge phenomena of ground water system. The rainfall acts as a most important factor in the development of agriculture and affects the economy of the country. Todd (1980) remarked that "Ground water levels may show seasonal variation due to rainfall. Drought extending over a period of several years, contribute to declining water level". The rainfall data analysis of Katthiwada area in Alirajpur district show a fairly good range of variation pointing out the positive as well as negative trends that affect the recharging system of the ground water reservoir. The present trend of over exploitation and inadequate rainfall is causing depletion in the ground water levels.
The ground water recharge phenomena may be improved by augment of rainwater. It is proposed that launching of suitable measure may provide remedy in minimizing the rapidly developing situation of ground water level depletion resulting in the drought conditions in Katthiwada area of Alirajpur district.

Conclusion

The paper provides a variation trend of rainfall data in Katthiwada area of Alirajpur district. The present rainfall data analysis indicates a range from 392.42 to 1562.32 with an average of 835.27 mm. The statistical measurement of the rainfall data indicate that the mean (862.85 mm), median (884.84 mm), mode (950 mm), standard deviation (281.51 mm), co-efficient of dispersion (0.326) ,co-efficient of variation (32.62) and co-efficient skewness (-0.30). The statistical measurement gives a precise value of rainfall data and its reveals a good variation values indicating significant fluctuation trend. The environmental impacts of rainfall variation on the ground water system have been discussed it has been observed that rainfall directly controls the recharging system of ground water reservoir.

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