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Effects of Rainfall Factor on Hydrogeological System Recharge in Bangar Environs: A Middle Part of India

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Abstract

Rainfall is one of the vital hydrometrological factors that govern the phenomena of groundwater system recharge. The results of rainfall data analysis of Bangar area of Dewas district located in Madhya Pradesh, India, and their environmental effects on groundwater system have been in corporate here in this paper. Rainfall phenomena reflect environmental scenario particularly climate change the data are subjected to several techniques of analysis. The years revealing more than the average annual rainfall values indicate positive recharge trend. The years reflecting less than the average value indicate negative trend of recharge to groundwater system. Cumulative departure exhibit positive and negative trends and the determination of moving rainfall average provide a picture of cycle variation of rainfall trend. Rainfall departure trend indicates higher values which reflect positive trend of recharge. Mathematical analysis indicate both positive and negative trend of groundwater recharge. Statistical analysis rainfall data have been determined value of mean, median, mode and the co-efficient standard deviation, co-efficient of dispersion, co-efficient of variation and co-efficient of skewness. The statistical data prove the validity of rainfall data. Environmental effects of rainfall factor have been discussed. It is suggests that implementation of a rainfall augmentation sachem would provide appropriate rainfall recharge to the groundwater system and it would also resolve the water crises problem.

Keyword: Rainfall, Time series, Moving average, Trends, Statistical analysis, Environment.

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1. INTRODUCTION

The term ‘Precipitation’ has been defined by Wiesner (1970) as “the deposition of water from the atmosphere on to a surface”. The precipitation occurs in different forms such as rain, dew, fog, cloud, frost, drizzle, hail and sleet. The liquid form of the precipitation is generally called as the ‘Rainfall’. Rainfall is one of the most affective hydro-meteorological factors and plays a governing role in the recharge of the ground water reservoir, as well as in the estimation of water balance of a basin. The usage of term rainfall has been favored in the present study.

Rainfall is usually expressed in the depth of the precipitated in the inches, measured by the rain gauges for selected period of the time. Rainfall is not an accurate losses as well as travel time for the vertical percolation in the permeable formation to several months or years for deep water tables underlying sediments with low vertical permeability. The measurement of rainfall is the expressed in mm, cm, or inches by rain gauges (Todd, 1980, 2010). According to Karanth, (1987, 2003) precipitation is “the atmospheric discharge of water in the solid or liquid state on the earth’s surface. Precipitation intensity is the rate of precipitation expressed in inches, cm or mm per minute, hour”. Rainfall, the primary source of the water that occurs as a result of the condensation of the atmospheric moisture, is governed by the science of the meteorology and therefore is considered to be one of the most important meteorological elements. Rainfall data are used for the design and construction of the water resource. (Rakhecha and Singh, 2009).

Rainfall is usually expressed in depth of precipitated water in inches, measured by rain gauges for selected periods of time (Tolman, 1937). Precipitation is recorded by gauges; its gauges consist of a rain collector at the top and a receptacle below, with a funnel in between. The rainfall amount is measured either by a graduated dip or a measuring cylinder (Karantn, 1987). Reddy (2013) described Precipitation is usually measured in millimeters and tenths of millimeters, If less than 1 mm, it is recorded as trace. Rainfall with intensity of 2.5 mm/h is called light rain and between 2.5 mm/h to 7.5 mm/h it is termed as moderate rain, when it exceeds 7.5 mm/h it is called heavy rain. In this paper, several approaches have been proposed for analyzing time series such as Graphical, Semi Average, Moving Average, Least square method. The purpose of this research is to detect best trend for the time series taken into account.

2. LOCATION OF STUDY AREA

The study area, around Bangar constitutes a part of Dewas district of Madhya Pradesh and limited within the latitudes 23^0 00’ to 23^0 05’N and longitudes 75^0 58’ 10’’ to 76^0 08’00’’E (Survey of India toposheet number – 46M/16 and 55 A/4, Fig. 1). The study area is located at a distance of 12 Km. from Dewas (longitudes 78^0 06' E latitudes 22^0 58' N, Figure 1) towards Ujjain.

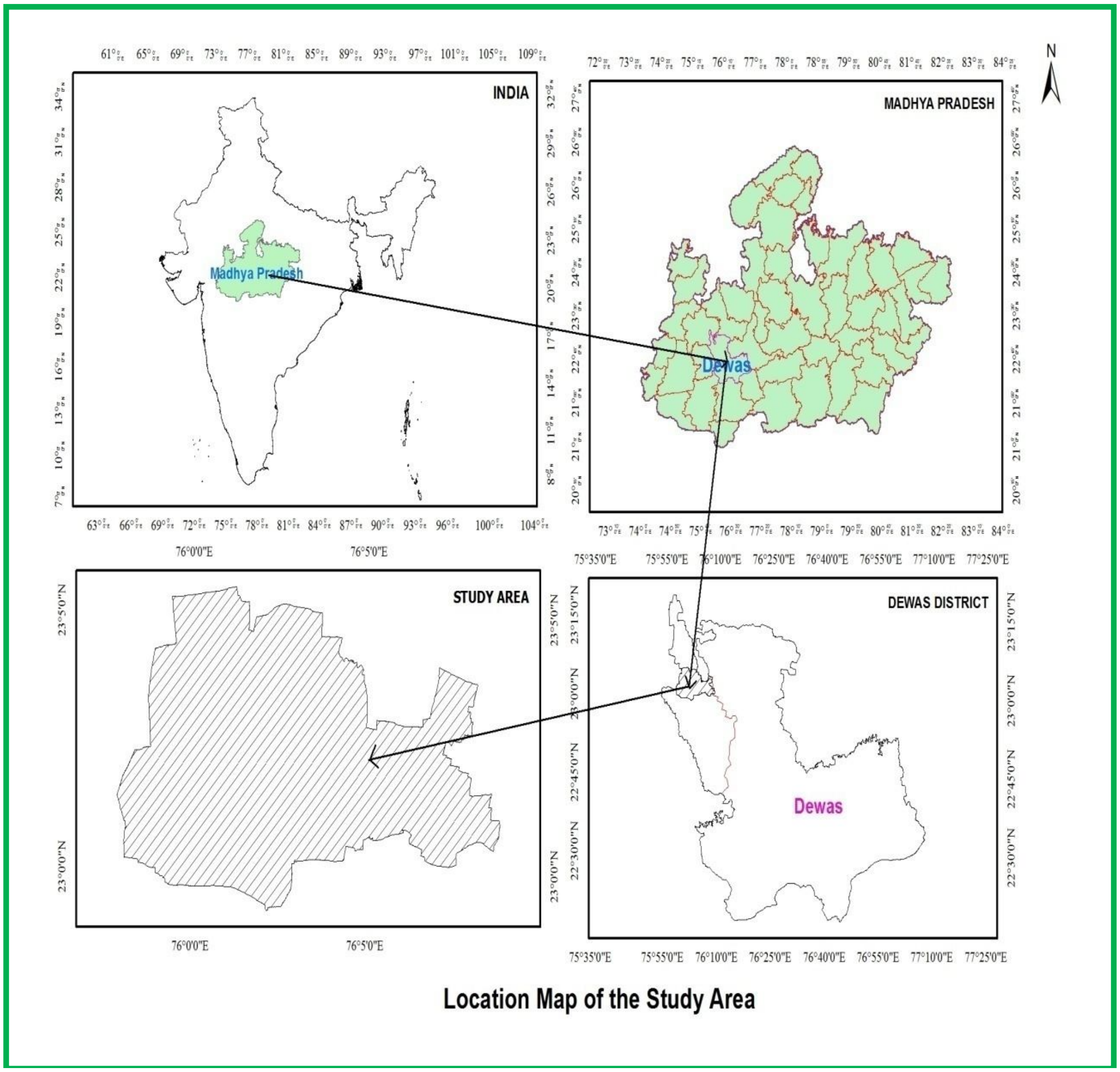

Fig. 1: Location Map of Bangar Study area Dewas District, Madhya Pradesh.

3. RAINFALL DATA ANALYSIS

The rate of rainfall is computed for a particular day or many of days from the records of daily readings of standard gauges. The rainfall data collected through the rain gauge are analyzed to observe the trend of rainfall distribution and intensities. Its amount and frequency mainly depend upon time and space. The monthly and annual rainfall data is computed on the basis of the daily rainfall data by simple addition of data. The mainly procedure of rainfall data analysis includes arithmetical and statistical methods (Raghunath, 1982).

3.1 ARITHMETICAL METHOD

The average rainfall for the Period of month's or the years is expressed by the arithmetic average of the period of the month's year. The variation in the rainfall is shown by the stable average. The rain fall data recorded for the period of 25 year (1991 - 2015) have been mentioned is the Table 1, based on the monthly record of the rainfall data the average value of annual rainfall has been determined. The minimum rainfall in last 25 years was recorded 440.6 mm in the year 2005, and the maximum rainfall recorded as 1366.0 mm during the year 2013. The average rainfall data of study area of Dewas district has been calculated 909.376 (Table 1, Figure 2).

S. No	Year / Month	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Year Total
1	1991 – 92	117.0	441.0	236.7	12.0	-	-	-	-	-	-	-	-	806.8
2	1992 – 93	75.5	163.1	206.7	81.0	50.0	-	-	-	-	-	-	-	576.3
3	1993 – 94	93.7	519.3	352.0	213.0	-	-	-	30.0	0.2	-	-	-	1208.2
4	1994 – 95	219.5	307.0	374.0	151.5	-	-	-	34.0	-	17.5	-	-	1103.5
5	1995 – 96	106.0	334.5	223.5	199.0	-	-	-	-	-	-	-	-	863.0
6	1996 – 97	20.0	511.5	368.5	188.0	27.0	-	-	-	-	-	-	-	1095.0
7	1997 – 98	127.0	414.5	307.0	51.0	32.5	11.0	16.0	-	-	-	-	-	1061.0
8	1998 – 99	166.8	296.7	102.5	376.5	35.0	-	-	-	99.0	-	-	-	1076.5
9	1999 – 00	186.3	217.4	100.4	248.7	185.2	-	-	-	-	-	-	20.0	958.0
10	2000 – 01	64.4	260.8	148.8	33.3	-	-	-	-	-	-	-	-	507.0
11	2001 – 02	138.8	266.7	196.5	36.6	155.2	-	-	-	29.0	-	-	-	822.8
12	2002 – 03	223.0	97.6	295.2	166.4	-	-	-	-	-	-	-	-	782.2
13	2003 – 04	98.6	459.0	153.4	457.2	-	-	-	-	-	-	-	-	1168.2
14	2004 – 05	36.6	197.6	359.3	57.4	12.4	-	-	-	-	-	-	-	660.3
15	**2005 – 06**	42.2	163.7	115.6	119.1	**-**	-	-	-	-	**-**	**-**	**-**	**440.6**
16	2006 – 07	29.4	203.8	607.9	366.4	1.3	-	-	-	-	-	-	-	1208.8
17	2007 – 08	53.8	465.0	254.2	112.0	-	-	-	-	-	-	-	-	885.0
18	2008 – 09	113.8	235.5	192.8	90.8	22.0	-	-	-	-	-	-	-	654.9
19	2009 – 10	59.8	327.0	100.0	92.0	137.0	-	-	-	-	-	-	-	715.8
20	2010 – 11	53.3	121.5	423.2	108.8	-	-	-	-	-	-	-	-	706.0
21	2011 – 12	104.9	367.6	461.0	114.0	-	-	-	-	-	-	-	-	1047.5
22	2012 – 13	-	472.0	235.0	523.0	8.0	-	-	-	-	-	-	-	1238.0
23	**2013 – 14**	249.0	604.0	398.0	68.0	45.0	-	2.0	-	-	-	-	-	**1366.0**
24	2014 – 15	15.0	315.0	87.0	220.0	7.0	-	-	44.0	-	31.0	-	-	719.0
25	2015 – 16	59.5	457.0	245.0	196.0	31.5	38.8	35.5	-	-	-	-	-	1064.0
Total		**2453.9**	**8218.7**	**6544.2**	**4281.7**	**749.1**	**151.8**	**53.5**	**108.0**	**128.2**	**48.5**	**0.0**	**20.0**	**22734.4**
Ave.		98.15	328.74	261.76	171.26	29.96	6.07	2.14	4.32	5.12	1.94	0.0	0.8	**909.37**

Table 1: Annual and Monthly Rainfall data from 1991 – 2015 in respect of Dewas District, Madhya Pradesh.

The graphic representation is exhibit consideration variation in the amount of the annual rainfall, computed average seasonal rainfall and others (Figure 2, 3). The seasonal variation of rainfall data of study area of Dewas district is given by the average monthly rainfall from 1991-2015 (Table 2, Figure 4). The monsoon seasonal average of rainfall has been calculated as 214.98 mm. The minimum rainfall has been noted during winter seasons 10.62 mm.

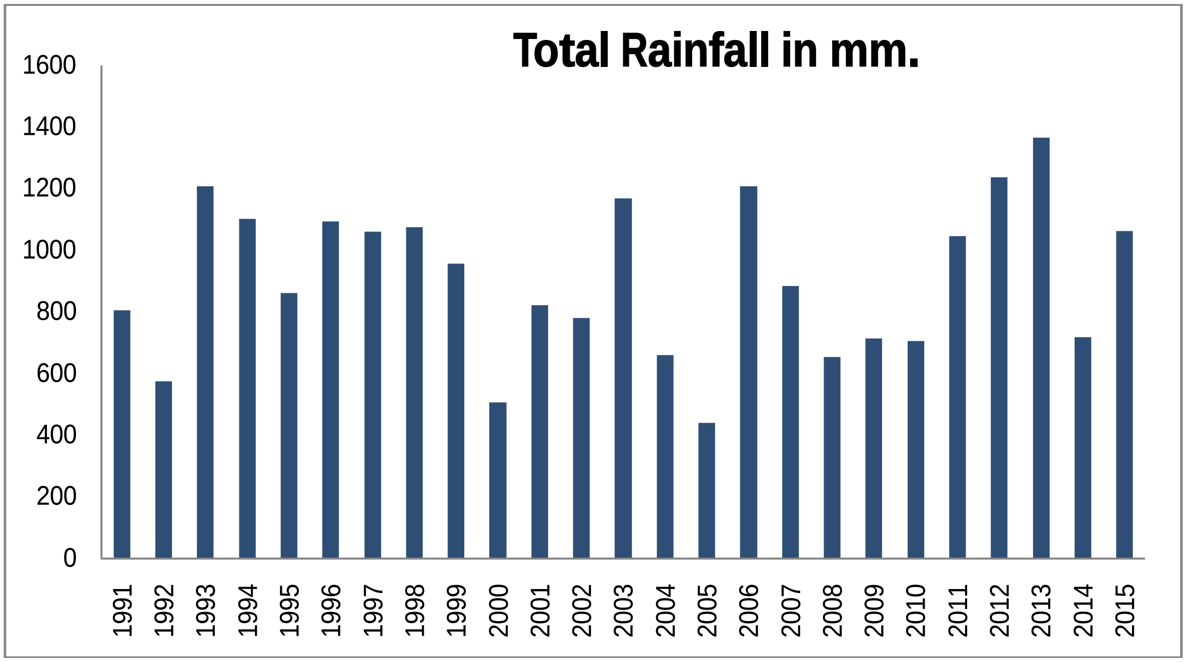

Fig. 2: Total annual rainfalls in mm. for the period of 1991- 2015.

Table 2: Computed Average Seasonal Rainfall of Dewas Area, Madhya Pradesh

S. No.	Seasons	Months	Mean monthly Rainfall (in mm)	Average rainfall (In mm.)
1.	Monsoon	June	98.15	214.98
		July	328.74	
		August	261.76	
		September	171.26	
2.	Winter	October	29.96	10.62
		November	6.07	
		December	2.14	
		January	4.32	
3.	Summer	February	5.12	1.96
		March	1.94	
		April	0.0	
		May	0.8	
Total			**910.26**	**227.56**

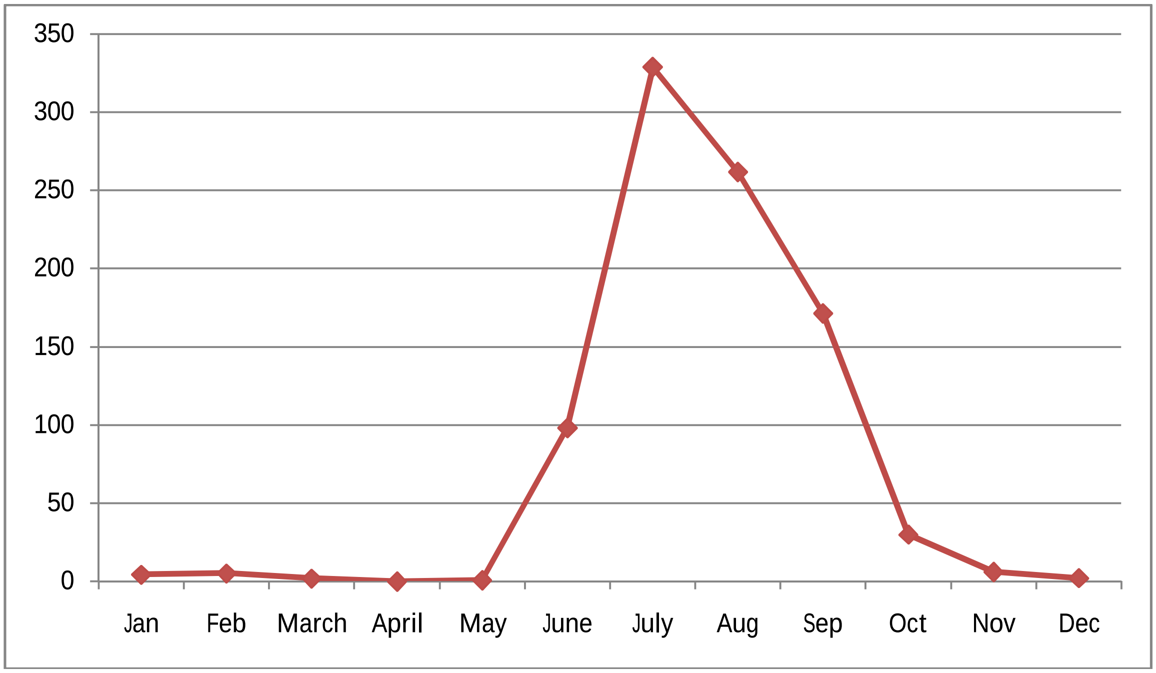

Fig. 3: Average monthly rainfalls in mm for the period of 1991-2015**.**

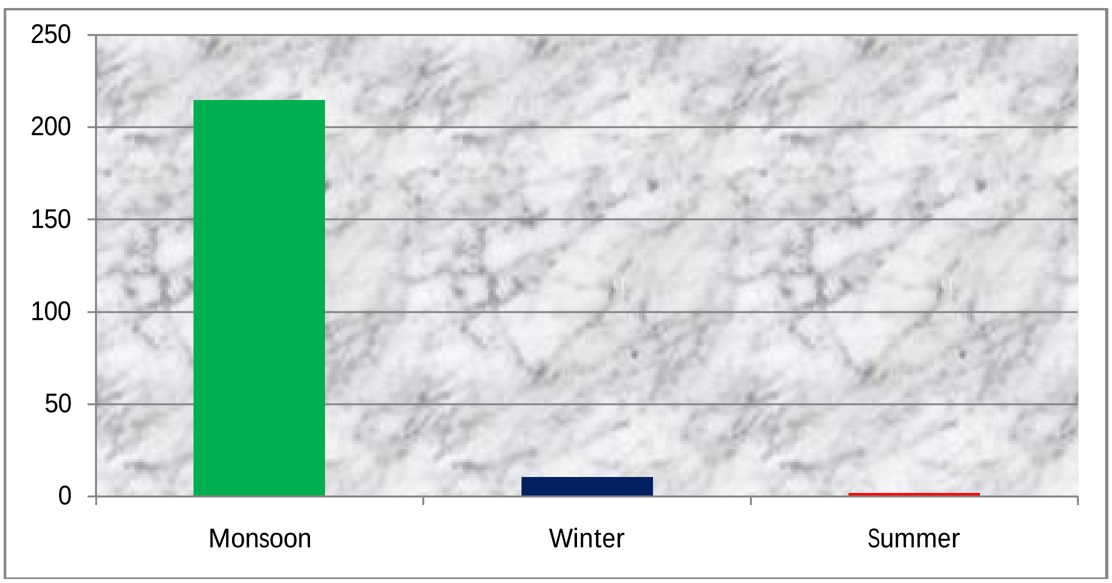

Fig. 4: Seasonal distributions of average rainfall data.

Table 3: Annual rainfall departure and cumulative departure from the annual average rainfall in Dewas district, Madhya Pradesh**.**

S. No.	Years	Total rainfall (mm)	Departure from average(mm)	Cumulative departure from average rainfall (mm)
1	1991	806.8	- 102.57	- 102.57
2	1992	576.3	- 333.07	- 435.65
3	1993	1208.2	298.82	- 136.82
4	1994	1103.5	194.12	57.29
5	1995	863.0	- 46.37	10.92
6	1996	1095.0	185.62	196.54
7	1997	1061.0	151.62	348.16
8	1998	1076.5	167.12	515.29
9	1999	958.0	48.62	563.91
10	2000	507.0	- 402.37	161.54
11	2001	822.8	- 86.57	74.96
12	2002	782.2	- 127.17	- 52.21
13	2003	1168.2	258.82	206.61
14	2004	660.3	- 249.07	- 42.46
15	2005	440.6	- 468.77	- 511.24
16	2006	1208.8	299.42	- 211.81
17	2007	885.0	- 24.37	- 236.19
18	2008	654.9	- 254.47	- 490.66
19	2009	715.8	- 193.57	- 684.24
20	2010	706.0	- 203.37	- 887.62
21	2011	1047.5	138.12	- 749.49
22	2012	1238.0	328.62	- 420.87
23	2013	1366.0	456.62	35.75
24	2014	719.0	- 190.37	- 154.62
25	2015	1064.0	154.62	0
Total		**22734.4**		

Departure and cumulative departure from the average rainfall have been calculated and recorded rainfall value in Table 3 and the nature of rainfall pattern has also exhibited by graphic method.

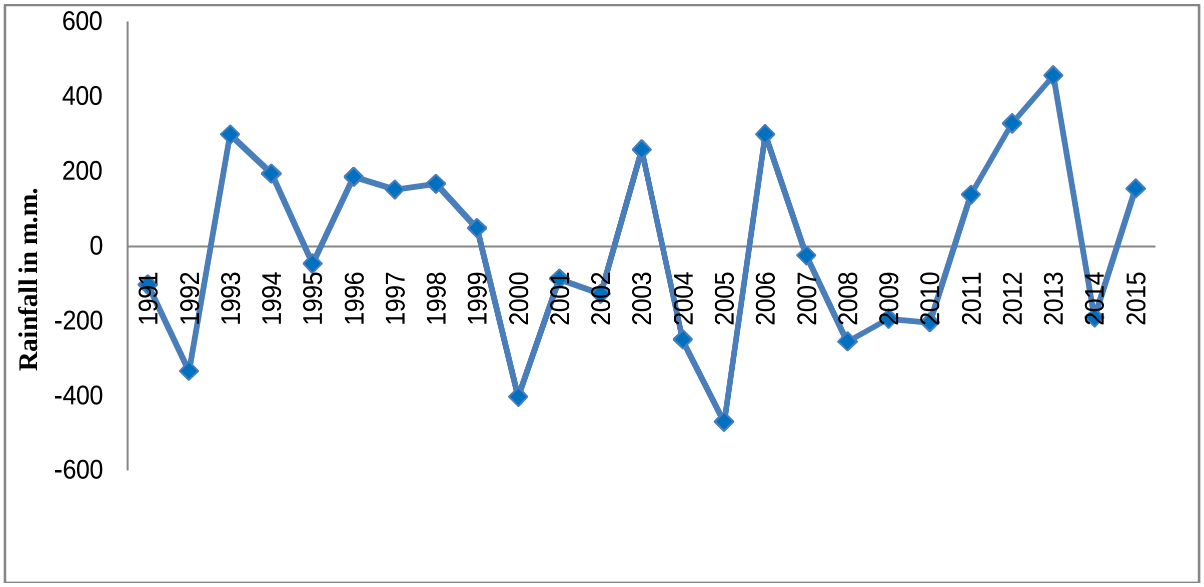

Fig. 5: Departure from average rainfalls for the period of 1991- 2015 of the Dewas district, Madhya Pradesh.

departure of rainfall more than average value have been noted during the years of 1993, 1994, 1996 – 1999, 2003, 2006, 2011 – 2013 and 2015, annual rainfall. These years revealing higher value of rainfall point out favorable period for the rain water recharge to the groundwater reservoir (Figure 5). The cumulative departure pattern graph show the maximum peak of rainfall was recorded during the years 1991, 1993 – 1994, 1996 – 1999, 2003, 2013 and 2015. These peaks indicate the prevalence of favorable periods for sufficient infiltration water to the groundwater system (Figure 6).

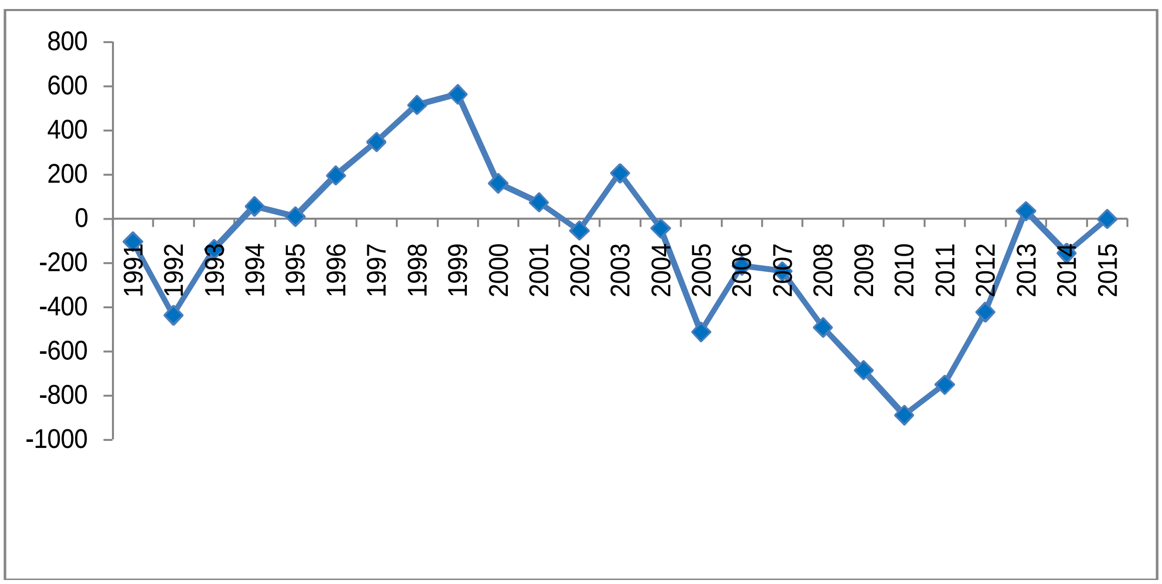

Fig. 6: Cumulative departures from average rainfall in mm for the period of 1991- 2015 of the Dewas district, Madhya Pradesh.

❖ MOVING AVERAGE CURVE (CYCLIC PATTERN)

The moving average curve smoothens out the extreme variations and indicate the trend or cyclic pattern, if any, more clearly. It is also known as the moving mean curve. The procedure to construct the moving average curve is as flows. The moving average curve is superimposed over the original rainfall series, though the variations in the original data are smoothened out to some extent in the moving average curve, no apparent trend (Table 4 Figure 7). The moving average curve is constructed with a moving period of *m* year, where *m* is generally taken to be 3 or 5 years. Let x_1, x_2, ……, x_n be the sequence of given annual rainfall in the chronological order. Let y_i denote the ordinate of the moving average curve for the *i*th year. Then for m = 3, y_i is computed from (Reddy, 2013).

$$y_i = x_{i-1} + x_i + x_{i+1}$$

Table 4: Computations for 3-year moving averages rainfall data of Dewas district, Madhya Pradesh.

S. No.	Year	Annual Rainfall x_i	Totals for moving average $= x_{i-1} + x_i + x_{i+1}$	Moving average y_i = Totals for moving average/3
1	1991	806.8	-	-
2	1992	576.3	806.8+576.3+1208.2 = 2591.3	863.76
3	1993	1208.2	576.3+1208.2+1103.5 =2888	962.66
4	1994	1103.5	1208.2+1103.5+863 =3174.7	1058.23
5	1995	863.0	1103.5+863+1095 = 3061.5	1020.5
6	1996	1095.0	863+1095+1061 = 3019	1006.33
7	1997	1061.0	1095+1061+1076.5 = 3232.5	1077.5
8	1998	1076.5	1061+1076.5+958 = 3095.5	1031.83
9	1999	958.0	1076.5+958+507 = 2541.5	847.16
10	2000	507.0	958+507+822.8 = 2287.8	762.6
11	2001	822.8	507+822.8+782.2 = 2112	704.0
12	2002	782.2	822.8+782.2+1168.2 = 2773.2	924.4
13	2003	1168.2	782.2+1168.2+660.3 =2610.7	870.23
14	2004	660.3	1168.2+660.3+440.6 = 2269.1	756.36
15	2005	440.6	660.3+440.6+1208.8 = 2309.7	769.9
16	2006	1208.8	440.6+1208.8+885 = 2534.4	844.8
17	2007	885.0	1208.8+885+654.9 = 2748.7	916.23
18	2008	654.9	885+654.9+715.8 = 2255.7	751.9
19	2009	715.8	654.9+715.8+706 = 2076.7	692.23
20	2010	706.0	715.8+706+1047.5 = 2469.3	823.1
21	2011	1047.5	706+1047.5+1238 = 2991.5	997.16
22	2012	1238.0	1047.5+1238+1366 =3651.5	1217.16
23	2013	1366.0	1238+1366+719 = 3323	1107.66
24	2014	719.0	1366+719+1064 = 3149	1049.66
25	2015	1064.0	-	-

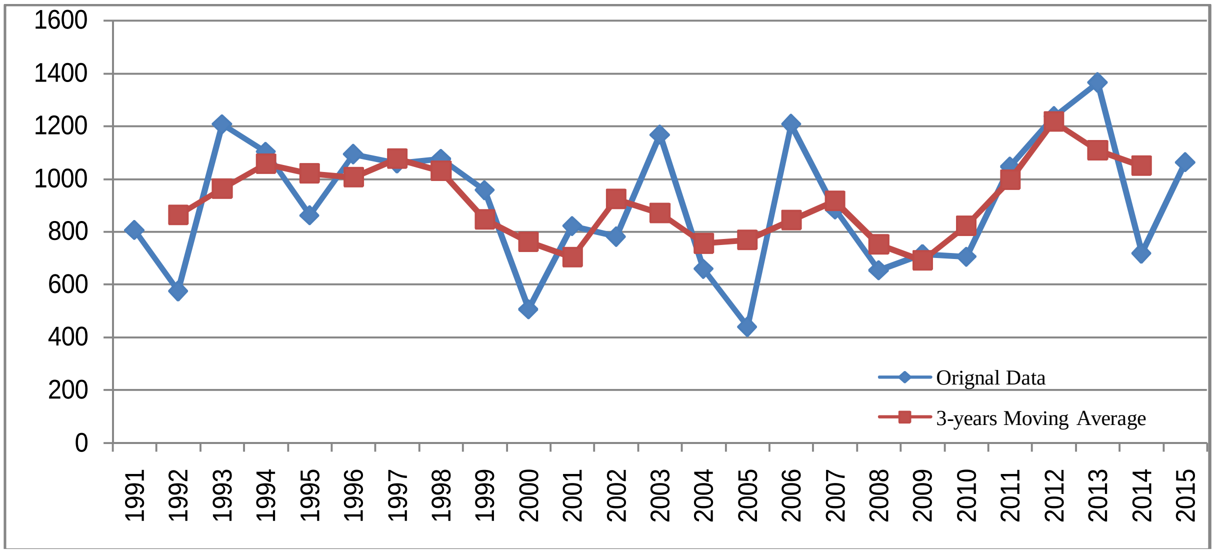

Fig. 7: Three year Moving Average curve of Rainfall data Dewas district, M.P.

3.2 STATISTICAL ANALYSIS

The statistical analysis employed for the study of rainfall data of Dewas district for a period of 25 years, 1991 to 2015. The determination include central tendency (mean, median and mode), coefficient of standard deviation, co-efficient of dispersion, co-efficient variation, co-efficient of skewness. The computed values of statistical parameter have been displayed (Table 5).

Table 5: Statistical parameter determination of rainfall of Dewas district M.P.

S. No.	Class Interval	Mid Value (x)	Frequency (f)	fx	$u = \frac{(x-A)}{I}$	fu	u²	fu²	Cumulative frequency
1	400 – 600	500	3	1500	-2	-6	4	12	3
2	600 – 800	700	6	4200	-1	-6	1	6	9
3	800 – 1000	900	5	4500	0	0	0	0	14
4	1000 – 1200	1100	7	7700	1	7	1	7	21
5	1200 – 1400	1300	4	5200	2	8	4	16	25
Total			**$\sum f = N = 25$**		**$\sum u = 0$**	**$\sum fu = 3$**	**$\sum u^2 = 10$**	**$\sum fu^2 = 39$**	

Mean:

Mean or arithmetic mean is the simple average of the different values of a variable. Its value is obtained by adding together all observation and by dividing this total by the number of observation. Mean is calculated by following formula:-

$$\textbf{Mean} = A + \frac{\sum fu}{N} \times I$$

Where,

A = Assumed mean = 900

I = Class interval = 200
fu = Frequency = 3
N= Total frequency = 25

$= 900+\frac{3}{25}\times 200$, $= 900+\frac{600}{25}$

= 900+ 24

The total mean rainfall of the district calculated as **924.0 mm**.

Median:

The median is the middle value of the distribution. Whenever the median is given as a measure, one-half of the observation in the distribution has a value the size of the median value or smaller and one-half have a value the size of the median value or larger (Davis, 1986). It is determined by the following formula-

Median = $l+\frac{h}{f}(\frac{N}{2}-c)$

Where,

l = Lower limit of median class = 800
f = Frequency of Median class = 5
h = Magnitude of Median class = 200
c = Cumulative frequency of the class preceding the median class = 9

N= Total frequency = 25

$= 800+\frac{200}{5}(\frac{25}{2}-9)$, $= 800+\frac{200}{5}(12.5-9)$

$= 800+40(3.5)$, $= 800+140 = 940.0$

Median = **940.0 mm.**

Mode:

A third type of “Central value” or “Center” of the distribution is the value of greatest frequency or, more precisely, of greatest frequency density. It is the value on the X-axis below the peak, or highest point of the frequency curve. This average is called the mode. In other words the value of the distribution is that value of the variety for which frequency is maximum. Mode is calculated by following formula-

Mode = $l+\frac{h(f-f_0)}{2f_1-f_0-f_2}$

l = lower limit of the modal class = 1000
f_0 = frequency of the modal class = 5
f_1 = frequency of the pre modal class = 7
f_2 = frequency of the post modal class = 4
h = Interval class =200

$= 1000+\frac{200(7-5)}{2\times 7-5-4}$

$= 1000+\frac{200\times 2}{5}$, = 1000 + 80

= **1080.0 mm.**

The computed value of mode 1080.0 mm indicates ideal rainfall for the area.

Co-efficient of Standard deviation:

The Standard Deviation is a parameter, which represents the variability and explains. How the individual values differ from the central value i.e., whether they are closely packed around the central or widely scattered away from it. Standard Deviation implies the positive square root of the arithmetic mean of the deviation of the value for the arithmetic mean (Gupta, 2006). It is determined by use the following formula –

Standard Deviation (δ) = I $\sqrt{\frac{(\sum fu_2)}{\sum f} - \frac{(\sum fu)_2}{\sum f}}$

Where,

δ. = Standard deviation

I = Class interval

$\sum f$ = N = Number of sample

$\sum fu^2 = 39$, $\sum fu = 3$

$\delta = 200\sqrt{\frac{(39)}{25} - \frac{(3)2}{25}}$, $= 200\sqrt{\frac{39}{25} - \frac{9}{25}}$

$= 200\sqrt{\frac{30}{25}}$, $= 200\sqrt{\frac{6}{5}}$

$= 200\sqrt{1.5}$, $= 200 \times 1.0954451$

= **219.0890** Standard Deviation

Co-efficient of Dispersion:

Co-efficient of Dispersion compares the variability of the two series, which differ widely in their averages or measured in different units. We do not merely calculate the measures of dispersion but we calculate the co-efficient of dispersion which is pure number, independent of the units of measurement. It is calculated by following method-

Co-efficient of Dispersion (CD) = $\frac{\delta}{M}$

Where,

δ= standard division = 219.0890, M = mean = 924.0

$= \frac{219.0890}{924.0}$, = **0.2371**

The calculated value of the Co-efficient of Dispersion represents that the amount of rainfall varies up to **0.2371**

Co-efficient of Variation:

Karl Pearson (*vide*, Gupta, 2006) has described that co-efficient of variation is the percentage variation in the mean, standard deviation being considered as total variations in the mean. For comparing the variability of two series, and calculate co-efficient of variation for each series. The series having greater coefficient of variance is said to be more variable then the other and the series having lesser co-efficient of variation is said to be more consistent than the other. It is percentage variation in the mean, standard deviation in the mean. Co-efficient of variation is calculated by this method –

Co – efficient of variation (CV) = $\frac{\delta}{M} \times 100$

Where,

δ= standard division = 219.0890

M = mean = 924.0

$$= \frac{219.0890}{924.0} \times 100$$

CV = **23.71**

Co-efficient of skewness:

Karl Pearson's co-efficient also known as Pearsonian co-efficient of skewness, is based upon the difference between mean and mode. This difference is divided by standard deviation to give a relative measure. There is no limit to this measure in theory and this is a slight drawback. But in practice, the value given by this formula is rarely very high and usually lies within ± 1(Gupta, 2006). The formula thus becomes:

Co-efficient of skewness = $\frac{(mean - \text{mode})}{\text{standard deviation}}$ or SK = $\frac{M - Mo}{\delta}$

M = mean = 924.0

Mo = mode = 1080.0

δ= standard deviation = 219.089

$$SK = \frac{924 - 1080}{219.0890}, \quad = \frac{-156}{219.0890}$$

SK = **- 0.712**

The co-efficient of skewness value has been determined -0.712 mm, and indicates that there is lack of symmetry in the rainfall amount.

3.3 ANALYSIS OF TIME SERIES

A time series determines a tendency to increase or decrease, over a specified period. 'This series provides an interesting illustration because the trend is usually predominant, virtually no other movement is discernable' (Croxton *et al,* 1988).

The time series analysis (TS) is a sequence of observation ordered in time. Mostly these observation are collected at equally spaced, discrete time interval, when there only one variable upon which observation are made then we call them a single time series or more specifically a univariate time series or more specification in any time series analysis is that some aspect of the past pattern will continue to remain in the future. Also under this setup, often the time series process is assumed to be based on past value of the main variable but not on explanatory variables (Ramasubramanian, 2007).

The method of fitting of second degree parabola has been adopted for the trend analysis of the behavior of annual rainfall. The parabola equation can be expressed as:

$$Yc = a + bx + cx^2$$

Where,

Yc = Trend value of dependent variables

x = Independent variable

a & b = Unknown

Similarly as in the case of a straight line, the normal equations for estimating a, b and c are given by:

$$\sum y = na + b\sum x + c\sum x^2 \quad \text{.................. (1)}$$
$$\sum xy = a\sum x + b\sum x^2 + c\sum x^3 \quad \text{.................. (2)}$$
$$\sum X^2y = a\sum x^2 + b\sum x^3 + c\sum x^4 \quad \text{.................. (3)}$$

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 determinations are made as per the following procedure:

$\sum y$ = 22734.4 $\sum x$ = 0, $\sum x^2$ = 1300
$\sum xy$ = 2945.5 , $\sum x^3$ = 0, $\sum x^2y$ = 1242405
$\sum x^4$ = 121420, n = 25

Substituting the above values in equation (1), (2) and (3),then equation in term of a, b and c are generated as given below:

$$22734.4 = 25a + (b\times0) + 1300c \quad \text{.................... (4)}$$
$$2945.5 = (a\times0) + 1300b + (c\times0) \quad \text{.................... (5)}$$
$$1242405 = 1300a + (b\times0) + 121420c \quad \text{.................... (6)}$$

By solving equation (4), (5) and (6) the values of a, b and c is obtained is given below:

a = 851.19, b = 2.266, c = 1.119

Therefore, an equation of parabola is developed, which can be written as:

$$Yc = 851.19 + 2.266x + 1.119x^2 \quad \text{.................... (7)}$$

With the help of equation (7) the trend values have been calculated which is shown in Table 6 and Figure 10.

Table 6: Time Series Analysis of rainfall data of the study area

No.	Year	t = x	y	x^2	Xy	x^3	x^2y	x^4	Trend Value(Yc)
1.	1991	-12	806.8	144	-9681.6	-1728	116179.2	20736	985.13
2.	1992	-11	576.3	121	-6339.3	-1331	69732.2	14641	961.66
3.	1993	-10	1208.2	100	-12082	-1000	120820	10000	940.43
4.	1994	-9	1103.5	81	-9931.5	-729	89383.5	6561	921.43
5.	1995	-8	863.0	64	-6904	-512	55232	4096	904.67
6.	1996	-7	1095.0	49	-7665	-343	53655	2401	890.15
7.	1997	-6	1061.0	36	-6366	-216	38196	1296	877.87
8.	1998	-5	1076.5	25	-5382.5	-125	26912.5	625	867.83
9.	1999	-4	958.0	16	-3832	-64	15328	256	860.03
10.	2000	-3	507.0	9	-1521	-27	4563	81	854.46
11.	2001	-2	822.8	4	-1645.6	-8	3291.2	16	851.13
12.	2002	-1	782.2	1	-782.2	-1	782.2	1	850.04
13.	2003	0	1168.2	0	0	0	0	0	851.19
14.	2004	1	660.3	1	660.3	1	660.3	1	854.57
15.	2005	2	440.6	4	881.2	8	1762.4	16	860.19
16.	2006	3	1208.8	9	3626.4	27	10879.2	81	868.05
17.	2007	4	885.0	16	3540	64	14160	256	878.15
18.	2008	5	654.9	25	3274.5	125	16372.5	625	890.49

19.	2009	6	715.8	36	4294.8	216	25768.8	1296	905.07
20.	2010	7	706.0	49	4942	343	34594	2401	921.88
21.	2011	8	1047.5	64	8380	512	67040	4096	940.93
22.	2012	9	1238.0	81	11142	729	100278	6561	962.22
23.	2013	10	1366.0	100	13660	1000	136600	10000	985.75
24.	2014	11	719.0	121	7909	1331	86999	14641	1011.51
25.	2015	12	1064.0	144	12768	1728	153216	20736	1039.51
Total		**$\sum x$ = 0**	**$\sum y$ = 22734.4**	**$\sum x^2$ = 1300**	**$\sum xy$ =2945.5**	**$\sum x^3$ = 0**	**$\sum x^2 y$ =1242405**	**$\sum x^4$ =121420**	

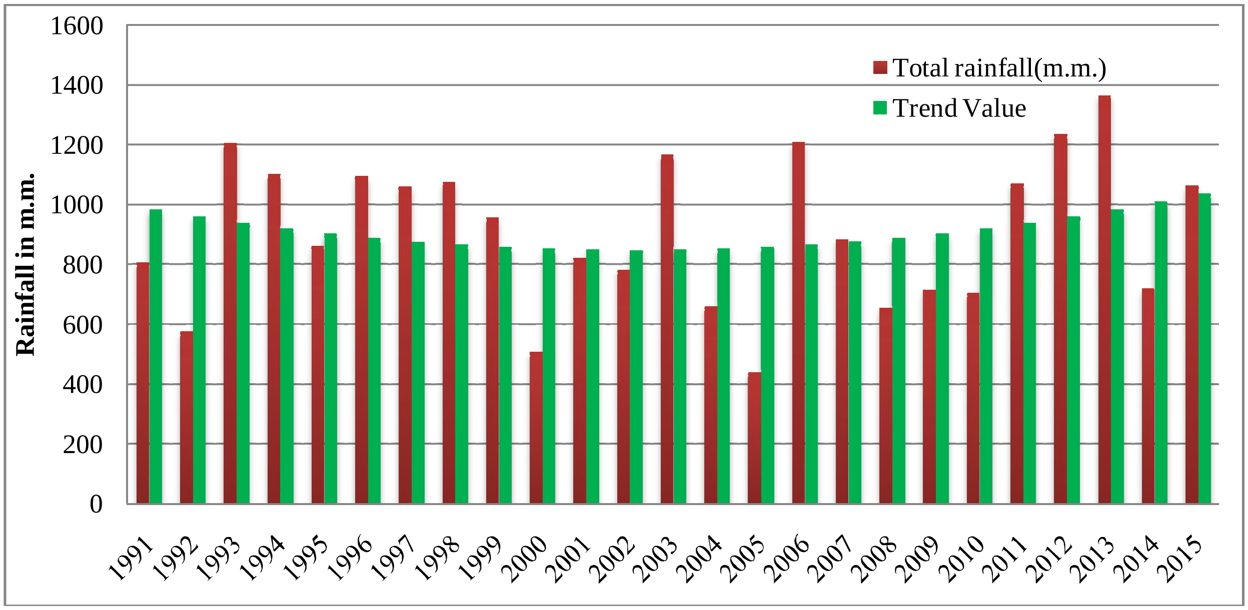

Fig. 8: Time Series of Analysis rainfall data 1991 to 2015 Dewas district, M.P.

The future forecast of rainfall amount for period of five years from 2016 to 2020 has been given below (Table 7, Figure 11):

Y_{2016} = $851.19 + 2.266 \times 13 + 1.119 \times (13)^2$ = 1069.759 mm.

Y_{2017} = $851.19 + 2.266 \times 14 + 1.119 \times (14)^2$ = 1102.238 mm.

Y_{2018} = $851.19 + 2.266 \times 15 + 1.119 \times (15)^2$ = 1136.955 mm.

Y_{2019} = $851.19 + 2.266 \times 16 + 1.119 \times (16)^2$ = 1173.91 mm.

Y_{2020} = $851.19 + 2.266 \times 17 + 1.119 \times (17)^2$ = 1213.103 mm.

Table 7: Estimated trend values of future expected rainfall (2016 – 2020)

S. No.	Year of forecast	Expected Rainfall (mm.)
1	2016	1069.759
2	2017	1102.238
3	2018	1136.955
4	2019	1173.91
5	2020	1213.103

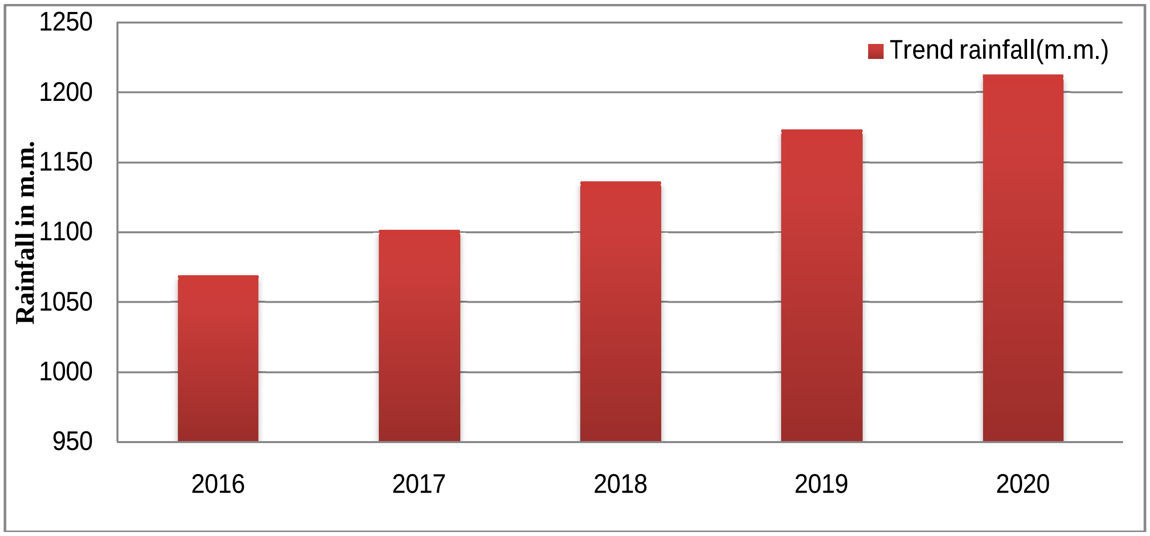

Fig. 9: Trend rainfall Value of 2016 to 2020 in Dewas district, M.P.

4. ENVIRONMENTAL IMPLICATION OF RAINFALL FACTOR

The rainfall factor plays a vital role in the recharge phenomena of the groundwater system the rainfall data analysis of Dewas study area conducted of period of 1991 – 2015. Indicate a range of rainfall from minimum 440.6 mm to maximum 1366.0 mm with an average of 909.376 mm. The rainfall data analysis point out a fairly good range of variation that compared to the rainfall average value that affecting recharges phenomena of the groundwater system of study area. The rainfall more than the average respect positive trend and less than the average value reveal negative trend of the recharge of rainwater to the groundwater system. The excess rainfall is resulting of several environmental problems such as disruption of communication system, loss of crops and vegetation, flooding and so on. The shortage of rainfall also causes and adverse environmental impact namely recharges phenomena of groundwater system, drought, loss of vegetation and agricultural growth, depletion of surface water resource and others.

The environmental consequences causes by rainfall factor can be control by augmentation of rainfall by contraction of artificial recharge structures and a forestation. The implementation of the appropriate measures to enhance the rainfall that will control the prevailing situation of depletion of water resources including groundwater resources, which is facing the rapid depletion of groundwater levels due to trend of population growth, organization, industrialization and energy sector.

5. CONCLUSION

The paper has provided a comprehensive account of rainfall data analysis and its implication on the recharge of groundwater system of Bangar area Dewas district Madhya Pradesh in India. The rainfall data of 25 year (1991 - 2015) have been analyzed by mathematical and statistical technique. Mathematical analysis of rainfall data indicates range from 440.6 to 1366.0 with an annual average of 909.376 mm. The delineation of annual departure with respect to annual average rainfall and cumulative departure indicate both positive and negative trends. The years of 1991, 1992, 1995, 2000 – 2002, 2004, 2005, 2007 – 10 and 2014 point out a negative trend. The positive cumulative trends have been observed during the years of 1994 – 2001and indicate negative trend during years of 1991 – 1993, 2002, 2004 – 2012 and 2014. The Statistical analysis rainfall data determined the value of mean: 924.0 mm, median: 940.0 mm, mode: 1080.0 mm and the co-efficient standard deviation: 219.089, co-efficient of dispersion: 0.233, co-efficient of variation: 23.307 and co-efficient of skewness: - 0.712. The statistical data prove the validity of rainfall data.

Environmental effects of rainfall factor have been discussed. It is recommended that implementation of a rainfall augmentation sachem would provide appropriate rainfall recharge to the groundwater system and it would also resolve the water crises problem. These peaks indicate the prevalence of favorable periods for adequate infiltration water to the groundwater system. The statistical analysis provides précised values of rainfall data variable. The time series analysis suggests the future trend of expected rainfall. It is suggested that the optimum development of rainwater harvesting will provide solution to the prevailing problem of acute shortage of water supply in Bangar-Dewas region. The augmentation of ground water reservoir by increasing rainwater and execution of scheme for a forestation would help to cater the demand of water supply to inhabitant of Bangar area.

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