

Role of Rainfall Variation Trends in Recharge of Ground water system of Barwani Area, Barwani District, Madhya Pradesh, India

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Abstract

This paper deals with an account of rainfall variation trend analysis and impacts on the recharge of ground water system of Barwani area, confined to Barwani district, Madhya Pradesh, India. Rainfall data for a period of 31 years (1985 to 2015), have been treated with methods of mathematical and statistical analyses. The mathematical analysis reveals that the minimum rainfall of 420.4 mm has been recorded during the year of 2000, and maximum rainfall of 1288.1 mm has been observed during the year of 2006. The calculated value of annual average rainfall has been determined as 742.8 mm. The departure from the annual average rainfall indicates both the positive and negative trends, whereas the cumulative departure points out negative trend of recharge. The statistical analysis of rainfall data involves the computation of central tendencies (Mean = 735.48 mm, Median = 750 mm, Mode = 775 mm.), and Standard Deviation = 192.64 mm, Coefficient of Dispersion = 0.261, Coefficient of Variation = 26.19 and Coefficient of Skewness = (- 0.205). These parameters indicate rather negative trend of recharge phenomena.

The environmental impacts of rainfall pattern on the recharge of ground water system have been discussed. The results of rainfall data analysis provide encouraging rainfall trend for the recharge of ground water system. The launching of proper programme for augmentation of rainfall phenomena by a forestation, which would increase the recharge of ground water resource by the implementation of rainwater harvesting system. The increase in rainfall would enhance the recharge of ground water system. The suggested measure would provide remedy to resolve the existing problems of sustained water supply to inhabitants of Barwani area.

Keywords: Rainfall, Variation trend, Ground water recharge, Barwani area, Barwani district, Madhya Pradesh, India.

Introduction

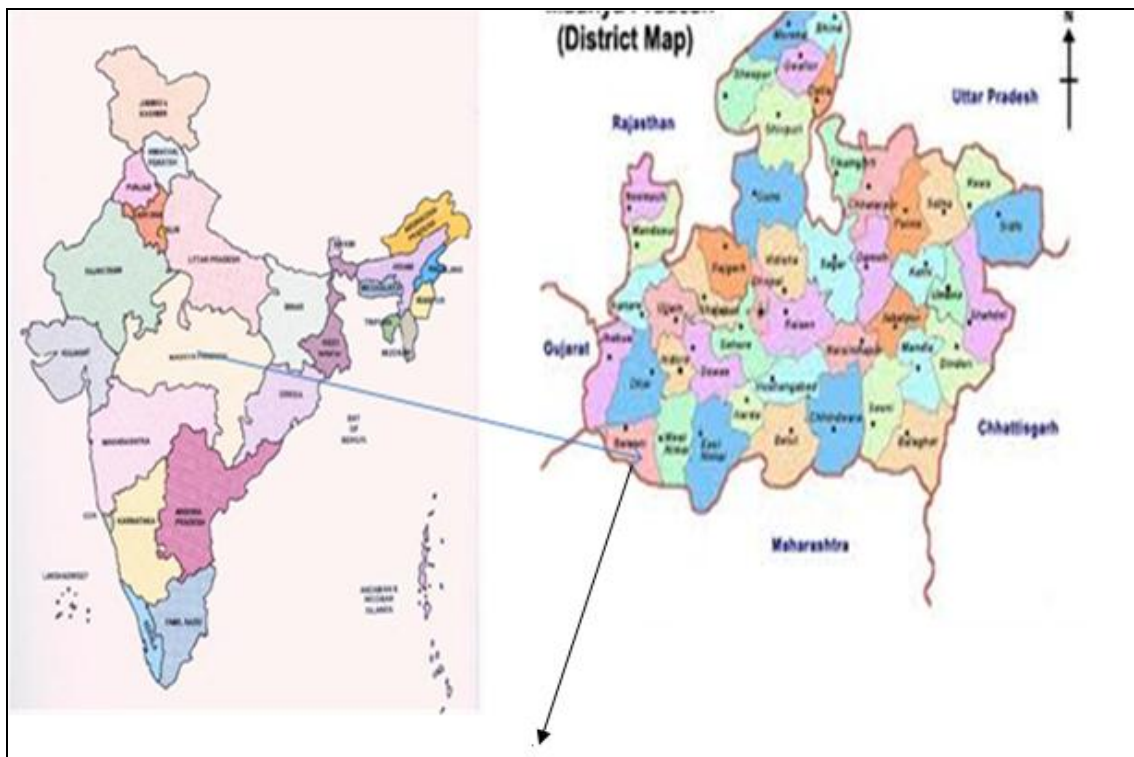
Rainfall is one of the most significant hydrometeorological parameters that govern the recharge phenomena of the ground water system. Rainfall phenomena also play an important role in the estimation of water balance status of a basin or a particular area. The rainfall (precipitation) has been defined by Wiesner (1970) ^[12] as "precipitation is the depositing of water from atmosphere on to a surface. This deposit may be either liquid or solid to give the various forms are precipitation".

The spatial differences in trends occur as a result of spatial differences in the changes in rainfall and temperature and spatial differences in the catchments characteristics that translate meteorological inputs into hydrological response (Burn and Elnur, 2002) ^[11]. Sahai *et al.*, (2003) ^[9] remarked that the changing precipitation pattern, and its impact on surface water resources, is an important climatic problem at present. Goswami *et al.* (2006) ^[6] conducted experiment by using a high resolution on a daily basis rainfall data set exhibited that there are significant rising trends in the frequency and magnitude of extreme rain events over central India during the monsoon season. Falahah and Suprpto (2010) ^[5] remarked that rainfall requires the occurrence of a thick layer of the atmosphere to have temperatures above the melting point of water near and above the Earth's surface.

The rainfall records exhibit a wide variation range in the amount and frequencies from the place to place. In India, rainfall mostly occurs during the monsoon period. The amount and frequency of rainfall reveal relevance in perceptiveness of the scope of surface runoff to ground water recharge. The rainfall variation trend analysis and environmental implications on ground water recharge of Barwani area is discussed herein the present paper.

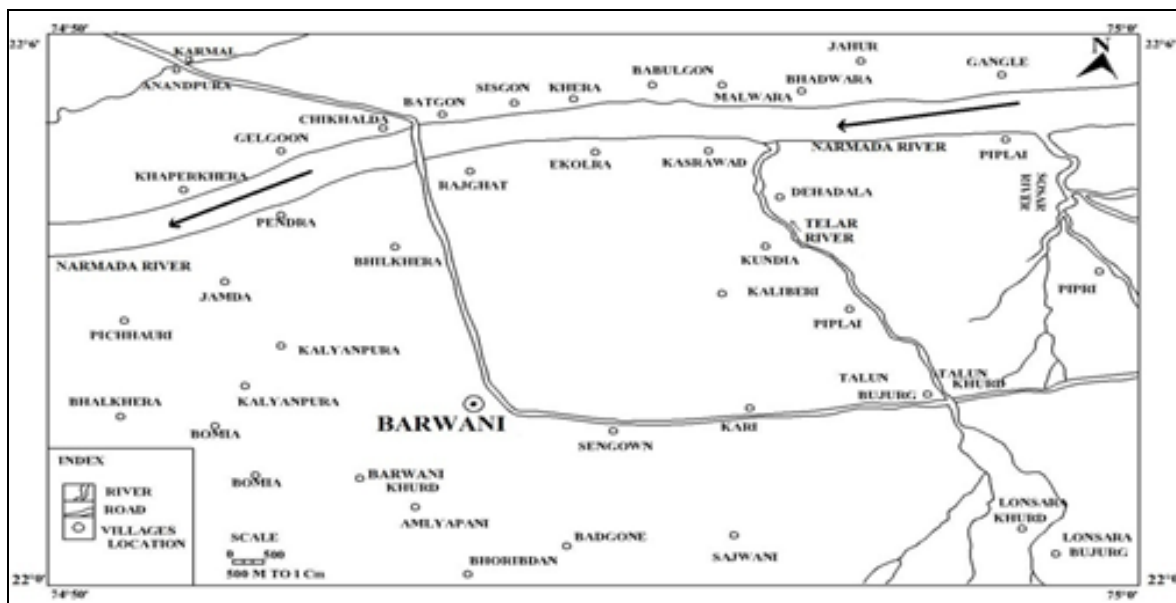
Study Area

Barwani study area is located in Barwani District, Madhya Pradesh, India within Latitude 22° 0' to 22° 6' N and Longitude 74° 50' to 75° 0'E (Survey of India Toposheet No. 46 J/16; Figure-1). The Barwani area is mainly drained by the Narmada River and its tributaries. Barwani is famous for Bawangaja (a holy place of Jain religion). The climate of Barwani area is pleasant and healthy. The temperature ranges from 7 °C. to 48 °C. The rainfall indicates a range from 600 to 700 mm.



A. Map of India

B. Map of Madhya Pradesh



C. Map of Study Area

Fig 1: Location map of Barwani study area. Madhya Pradesh, India

Rainfall Data Analysis

The annual rainfall data of last 31 years, (1985- 2015) have been collected from the district Collectorate Office, Barwani District, Madhya Pradesh. The data are displayed (Table 1).and subjected to the mathematical and statistical analyses.

1. Mathematical Method

The mathematical method is commonly used for rainfall data analysis. This method involves computation of the

average for the period of specific month or year as arithmetic mean. The determined values are expressed in mm. The range of variation in rainfall is indicated by a stable mean. The annual rainfall data of 31 years indicate that the minimum rainfall of 420.4 mm has been noted during the year of 2000, and the maximum rainfall has been observed as 1288.1 mm during the year of 2006. The annual average rainfall of the area for 31 years has been determined as 742.8 mm (Table 1, Figure 2).

Table 1: Rainfall data for a period of 1985-2015 in respect Barwani study Area, M. P, India.

S. No.	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1	1985	--	--	--	--	--	75.2	124.5	103.7	45.1	85	--	--	433.5
2	1986	--	--	--	--	--	117.7	204.6	241.4	28.2	5	--	--	596.9
3	1987	--	--	--	--	--	140.1	76.6	214.8	6.4	23.8	--	--	461.7
4	1988	--	--	--	--	--	91.2	309.2	208.8	275.9	75.1	--	--	960.2
5	1989	--	--	--	--	--	232.7	151.8	402.8	93	0	--	--	880.3
6	1990	--	--	--	--	--	75.6	277.2	354.3	222.3	58.7	--	--	988.1
7	1991	--	--	--	--	--	176.8	331.5	70.6	15.7	0	--	--	594.6
8	1992	--	--	--	--	--	180.6	85.7	203.3	74	99.2	--	--	642.8
9	1993	--	--	--	--	--	113.2	274.8	125.8	199.8	94.6	--	--	808.2
10	1994	--	--	--	--	--	191.6	245.2	324.4	251.5	1	--	--	1013.7
11	1995	--	--	--	--	--	39.6	281.4	115.2	182	38.4	--	--	656.6
12	1996	--	--	--	--	--	63.7	378.3	229	154.4	68	--	--	893.4
13	1997	--	--	--	--	--	149.5	276.8	296.3	78.1	8.1	--	--	808.8
14	1998	--	--	--	--	--	79.3	240.8	225.9	270.2	5	--	--	821.2
15	1999	--	--	--	--	--	91.6	80	220	97.9	--	--	--	489.5
16	2000	--	--	--	--	--	64.8	150.8	120.8	84.08	--	--	--	420.48
17	2001	--	--	--	--	--	49	183.3	201.3	108.3	--	--	--	541.9
18	2002	--	--	--	--	--	95.6	208.1	305.2	152.2	--	--	--	761.1
19	2003	--	--	--	--	--	163.5	201	290.9	166.8	12	--	--	834.2
20	2004	--	--	--	--	--	54	200	250.1	135.6	38.7	--	--	678.4
21	2005	--	--	--	--	--	67.4	150.9	199.1	105	3	--	--	525.4
22	2006	--	--	--	--	--	119.5	501.2	409.9	257.6	--	--	--	1288.2
23	2007	--	--	--	--	--	182.9	213.1	300	174	0	--	--	870
24	2008	--	--	--	--	--	90.8	220.1	298	113.1	8	--	--	730
25	2009	--	--	--	--	--	101	201	274	128.2	18	--	--	722.2
26	2010	--	--	--	--	--	87.3	211.2	299	149.4	--	--	--	746.86
27	2011	--	--	--	--	--	33.4	207.8	295.5	170.6	--	--	--	707.3
28	2012						105.5	140	180	116.5	38			579.5
29	2013		20		19.8		190.7	220.5	240.6	252.2	99.9			1043.7
30	2014						184.2	132.8	124.9	159.9	97.8		42.6	742.2
31	2015			44.9		60	154.6	173.7	191.6	95.5	66.4			786.7
Total			20	44.9	20	60	3563	6654	7317	4363	944		43	23027.64
Average			20	44.9	20	60	115	215	236	141	39		43	742.8

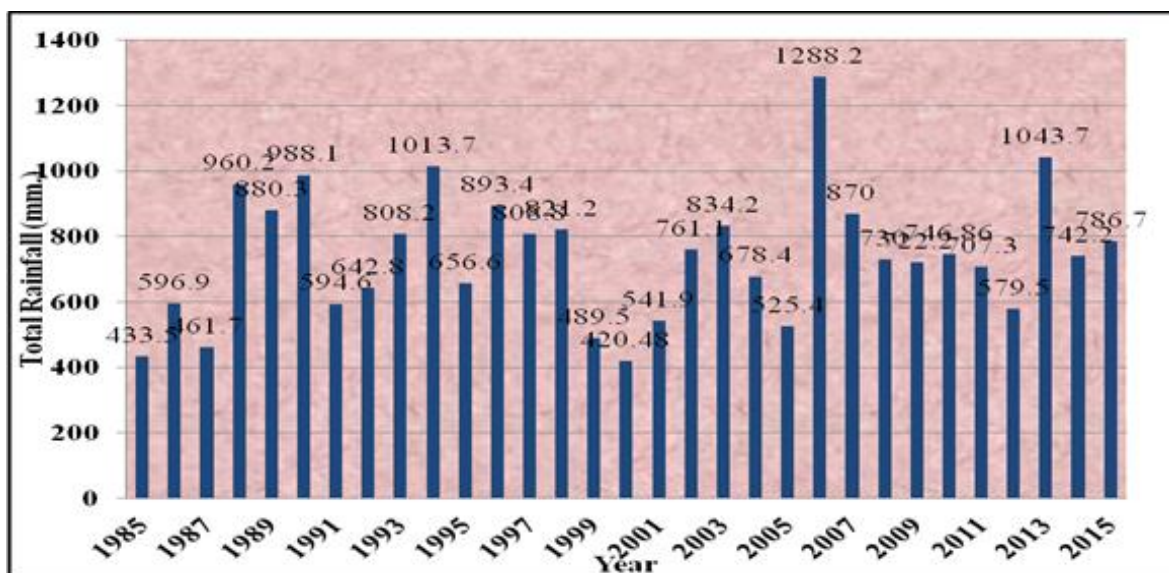


Fig 2: Total Annual rainfall of Barwani study area, Barwani district M.P. for the period of 1985-20115.

The average monthly annual rainfalls of Barwani area for the period of 1985 – 2015 have been displayed by graphical representation method. The minimum rainfall value as 20

mm (February and April) and the maximum rainfall of 236 mm during the month of August (Table 2, Figure 3).

Table 2: Average Monthly Rainfall of Barwani area Period for 1985-2015, Barwani district, Madhya Pradesh, India

S. No.	Month	Average Rainfall	Cumulative Average Rainfall
1	January	--	--
2	February	20	20
3	March	44.9	64.9
4	April	20	84.9
5	May	60	144.9
6	June	115	259.9
7	July	215	474.9
8	August	236	710.9
9	September	141	851.9
10	October	39	890.9
11	November	--	890.9
12	December	43	933.9

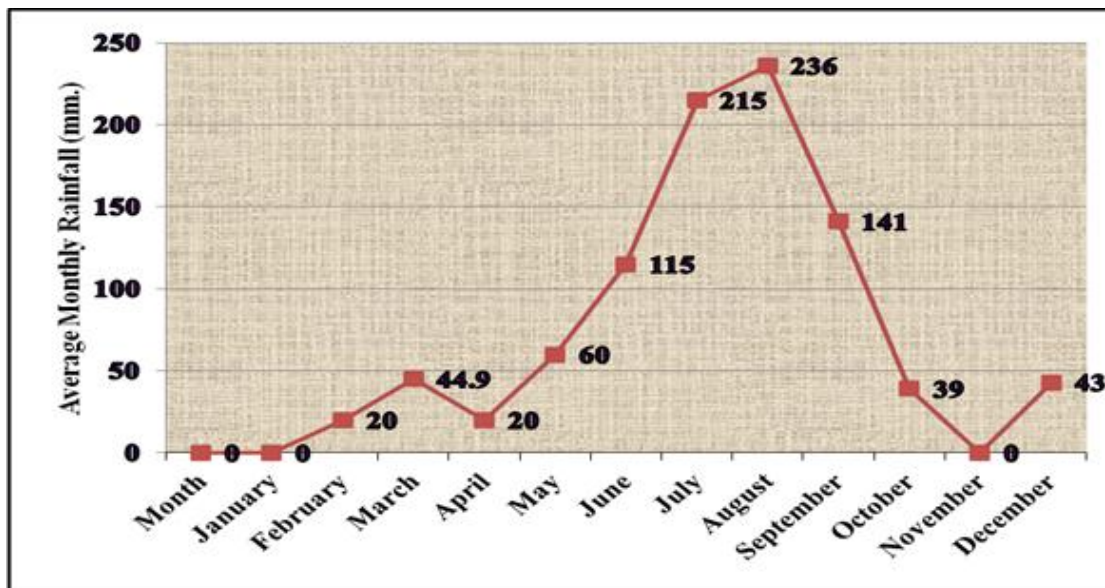


Fig 3: Average Monthly Rainfall of Barwani study Area (1985- 2015), Barwani district, Madhya Pradesh, India

Table 3: Departure from average rainfall and Cumulative departure from average Rainfall in Barwani area for the period of 1985-2015, Barwani district, Madhya Pradesh, India

S. No.	Years	Total Rainfall (mm.)	Departure from average rainfall	Cumulative departure from average rainfall
1	1985	433.5	-309.3	-309.3
2	1986	596.9	-145.9	-455.2
3	1987	461.7	-281.1	-736.3
4	1988	960.2	217.4	-518.9
5	1989	880.3	137.5	-381.4
6	1990	988.1	245.3	-136.1
7	1991	594.6	-148.2	-284.3
8	1992	642.8	-100	-384.3
9	1993	808.2	65.4	-318.9
10	1994	1013.7	270.9	-48
11	1995	656.6	-86.2	-134.2
12	1996	893.4	150.6	16.4
13	1997	808.8	66	82.4
14	1998	821.2	78.4	160.8
15	1999	489.5	-253.3	-92.5
16	2000	420.48	-322.32	-414.82
17	2001	541.9	-200.9	-615.72
18	2002	761.1	18.3	-597.42
19	2003	834.2	91.4	-506.02
20	2004	678.4	-64.4	-570.42
21	2005	525.4	-217.4	-787.82
22	2006	1288.2	545.4	-242.42
23	2007	870	127.2	-115.22

24	2008	730	-12.8	-128.02
25	2009	722.2	-20.6	-148.62
26	2010	746.86	4.06	-144.56
27	2011	707.3	-35.5	-180.06
28	2012	579.5	-163.3	-343.36
29	2013	1043.7	300.9	-42.46
30	2014	742.2	-0.6	-43.06
31	2015	786.7	43.9	0.84

Average Rainfall = 742.8 mm.

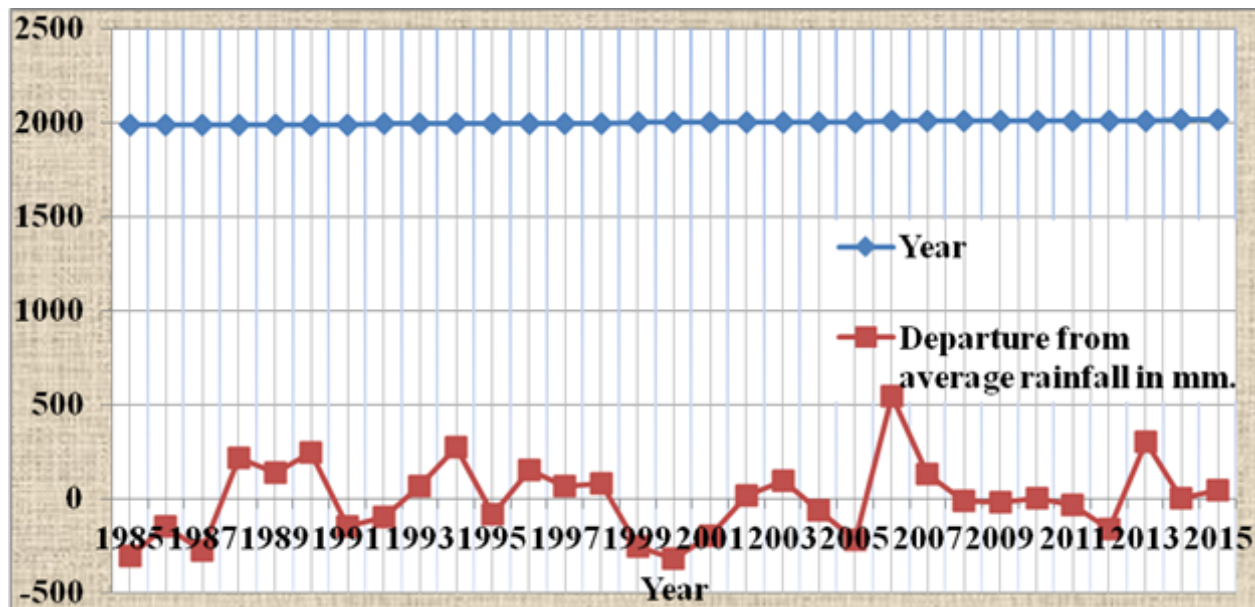


Fig 4: Departure of Average Rainfall of the Barwani study area (1985-2015), Barwani district, Madhya Pradesh, India

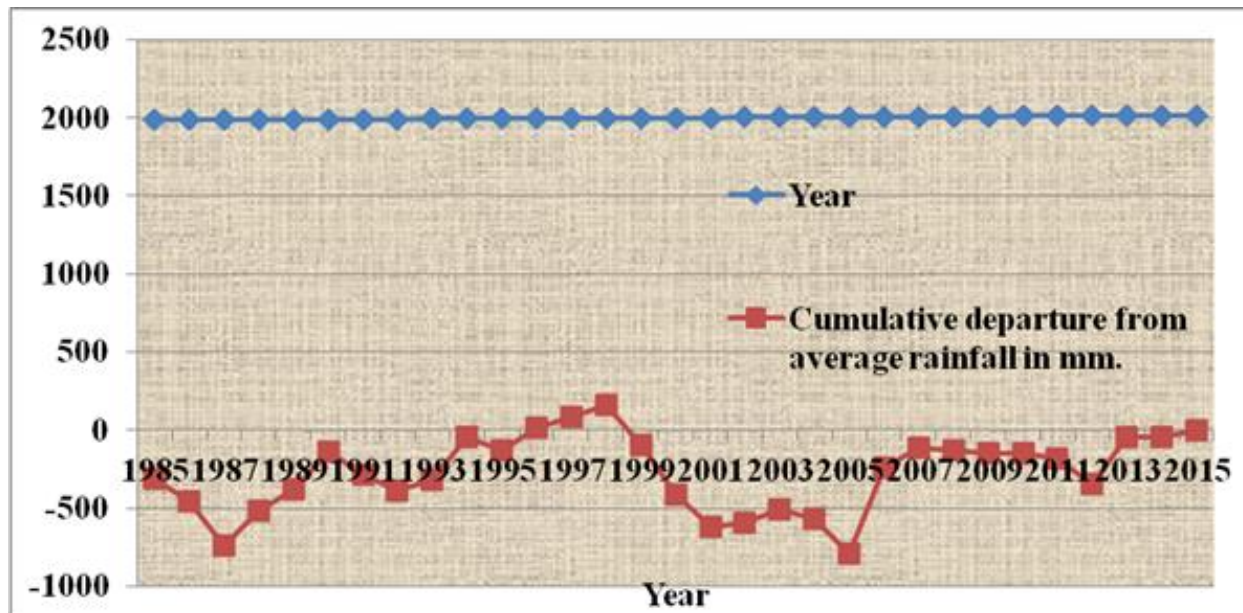


Fig 5: Cumulative departure of the Barwani Study Area for the Period 1985-2015, Barwani district, Madhya Pradesh, India.

The departure and cumulative departure for rainfall from the average rainfall during the period from the 1985 to 2015 have been displayed (Table 3). The graphical representation has been exhibited (Figure 4, 5). It has been observed that the rainfall departures from the average rainfall are of higher values during the years of 1988- 1990, 1993, 1994, 1996-1998, 2002, 2003, 2006, 2007, 2013 and 2015. The years indicating higher values

of departure from the average rainfall reveal favorable periods for the recharge of rainwater to the ground water storage. The annual departures from the average during the years of 1985-1987, 1991-1992, 1995, 1999-2001, 2004-2005, 2008-2012 and 2014 reflect rainfall amount lower the average annual rainfall. The years of low rainfall point out a negative trend, which causes depletion in the ground water levels in the Barwani study area.

2. Statistical Method

The statistical method for the analysis of rainfall data of Barwani study area for a period of 31 years (1985-2015), has been conducted to determine the central tendencies. (Mean, Median, Mode). Standard Deviation, Coefficient

of Dispersion, Coefficient of Variation, Coefficient of Skewness and Time Series analysis. Following the methods proposed by Davis (1986, 2002) [3, 4] and Croxton *et al.* (1988) [2]. The methods of computing of the rainfall are described underneath (Table 4):

Table 4: Computation of statistical Parameters of Rainfall data of Barwani study Area, Barwani district, Madhya Pradesh, India

Class interval	Mid- value (x)	Frequency (f)	$u=x-800/200$	fXu	u^2	fXu^2	Cumulative Frequency
300-500	400	4	$400-800/200 = -2$	-8	4	16	4
500-700	600	8	$600-800/200 = -1$	-8	1	8	12
700-900	800	14	$800-800/200 = 0$	0	0	0	26
900-1100	1000	4	$1000-800/200 = 1$	4	1	4	30
1100-1300	1200	1	$1200-800/200 = 2$	2	4	4	31
Total	4000	$f= N= 31$	$\Sigma u = 0$	$\Sigma fu = -10$	10	32	106

Mean

Arithmetic mean of a series is the number of obtained by dividing the total values of various items by their number the mean in another word for arithmetic average and is defined as the sum of all observation divided by the number of observation. Mean, for a set of observations is the sum divided by the expression as

Mean = $A + (I \times \Sigma fu) / N$

Where, A = Assumed mean =800, I = Class interval = 200, F = frequency = fu = -10

N = Total frequency = 31
 Mean = $800 + [200 (-10)] / 31$
 = $800 + (-2000) / 31$

Mean = 735.48

The mean rainfall of this are calculated as 735.48 mm.

Median

For a set of observation, median is the variable, which divided it into two equal parts. It is calculated by the formula.

Median (MD) = $L + i / f (N/2 - c)$

Where, L = Lower limit of median class = 700, i = Class interval = 200, N = Total

Frequency = 31, C = Cumulative frequency of the class preceding the Median

Class =12, Median class =12, f= Frequency of median class =14

$MD = 700 + 200 / 14 (31/2 - 12)$
 $MD = 700 + 14.29 (15.5 - 12)$
 $MD = 700 + 50$
 $MD = 750$

Median = 750 mm.

Mode

The mode is defined as the value, which occurs most frequency a given set of observation. It is calculated by the formula.

Mode (MO) =

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

Where, I = Lower limit of modal class = 700
 i = class interval = 200
 f_1 = Frequency of the model class = 14

f_0 = Frequency of class preceding the model class = 8

f_2 = Frequency of the just followed to the model class = 4

Mode (MO) = $700 + [200(14-8)] / [2 \times 14 - 8 - 4]$
 $MO = 700 + [200 \times 6] / 16$
 $MO = 700 + 75$
 $MO = 775 \text{ mm.}$

Standard Deviation

The standard deviation is positive square root of the arithmetic mean of the deviation of the given value for their arithmetic mean. The standard deviation has been defined as the, positive root of the arithmetic mean; it is given values for their arithmetic mean, (Gupta and Kapoor, 2003). Standard deviation is expressed by sigma (σ) and calculated by the expression:

$$\sigma = i / N \sqrt{\Sigma fu^2 - \left(\Sigma fu \right)^2 / N}$$

Where, σ = standard deviation

$\sigma = 200 / 31 \sqrt{32 \times (-10)^2}$ N = Total frequency = 31

$\sigma = 200 / 31 \sqrt{31 \times 32 \times 100}$ i = Class interval = 200

$\sigma = 200 / 31 \sqrt{992 \times 100}$ $fu^2 = 32, fu = -10$

$\sigma = 200 / 31 \sqrt{892}$
 $\sigma = 6.45 \times 29.86$
 $\sigma = 192.64$

Standard Deviation = 192.64

Co – Efficient Of Dispersion

The co – efficient of dispersion is measure of different units. We do not merely calculate the coefficient of dispersion, which are pure numbers independent of the units of measurement (Gupta and Kapoor, 2003). It is defined as measure of scattered ness and is determined by following expression -

Co-Efficient (CD) = Standard Deviation / Mean

Where,

Standard Deviation (SD) = 192.64
 Mean= 735.48
 CD = 192.64 /735.48
CD=0.261

CV= 100 × SD/Mean

Where, Standard Deviation (SD) = 192.64
 CV= 100×192.64 /735.48
 Mean = 735.48

CV= 26.19

Co-Efficient Of Skewness

The co-efficient of skewness is lack of symmetry in the given distribution. It is denoted by the symbol skewness and computed by using the formula.

Co – efficient of skewness = (Mean – Mode) / Standard Deviation.

Where, Mean =735.48
 Mode = 775 mm.
 Standerd Deviation (SD) = 192.64
 Skewness = (735.48–775)/ 192.64
 = - 39.52 / 192.64
 = - 0.205

The statistical analysis rainfall data of Barwani study area indicates values of mean =735.48 mm, Median = 750 mm, Mode = 775 mm, Standard deviation = 192.64, Co-efficient dispersion = 0.261, Co-efficient of variation = 26.19 and Co-efficient of skewness = - 0.205. The determined values of statistical parameters indicate a negative trend of rainfall.

Time Series Analysis

The results of time series analysis of rainfall data provide important information regarding the trend of a series of observation. It helps to measure the variation from the trend. Time series analysis is used as a tool to forecast the behavior of the future trend. The least square fit of straight line method has been employed for deducing the trend of the behavior annual rainfall. A time series determines a tendency to increase or decrease, over a particular period. ‘This series provides an interesting illustration because the trend is usually predominant, virtually no other movement is discernable’ (Croxtton *et al*, 1988) [2].

In time series analysis trend may be defined as “long-term change in the mean level” but trend analysis helps in finding ‘forecasting’. The basis of scientific forecasting is statistics. Trend analysis has been carried out to examine the long term trends in rainfall over different subdivisions. The rainfall trend is very crucial for the economic development and hydrological planning for the country. Long term trends of Indian monsoon rainfall for the

Co-Efficient Of Variation

The co-efficient of variation is the percentage variation in the mean, standard deviation in the mean, co-efficient of variation is calculated by the formula:

country as a whole as well as for smaller regions have been studied by research workers (Maraghatham, 2012). The straight-line equation can be expressed as –
 $Y_c = a + bx$

Where, Y_c = Trends value of dependent variables
 X = Independent variables

To establish a best fit straight line, the value of a and b must be determined from the observed data. This is done by simultaneous solving of two normal equations -

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

$$\sum x y = a \sum x + b \sum x^2 \dots\dots\dots (2)$$

The value of different elements in the above equation has been determined by Considering ‘y’ as variables (annual rainfall) and ‘x’ as constant (year), (Table 4.5).

The calculations are completed as per the following procedure

$$\sum y = 23027.64, \sum x = 0$$

$$\sum x y = 8432.4, \sum x^2 = 2480$$

$$N = 31$$

According to equation (1) and (2) two equations in term of A and B are determined-

$$23027.64 = 31a + b \cdot 0 \dots\dots\dots (3)$$

$$8432.4 = a(0) + b(2480) \dots\dots\dots (4)$$

Solving equation (3) and (4), the values of (1) and (2) are obtained respectively. The future forecast of rainfall amount of Ten year 2016 to 2025 has been attempted. There can be variation of ± 50 mm variations in the expected amount.

$$\sum y = Na + b \sum x$$

$$\sum xy = a \sum x + b \sum x^2$$

$$23027.64 = 31(a) + (b) \cdot 0 \quad 8432.4 = a(0) + b(2480)$$

$$23027.64 = 31a \quad 8432.4 = b(2480)$$

$$a = 23027.64/31$$

$$b = 8432.4/2480$$

$$a = 742.82$$

$$b = 3.400$$

According to the equation

$$Y_c = a + bx$$

$$Y_c = 742.82$$

$$Y_c = 797.22$$

Table 5: Time Series analysis of Rainfall data of the Barwani Study Area, Barwani district, Madhya Pradesh, India.

S. No.	Years	Total Rainfall (mm.)Y	X	XY	X ²
1	1985	433.5	-15	-6502.5	225
2	1986	596.9	-14	-8356.6	196
3	1987	461.7	-13	-6002.1	169
4	1988	960.2	-12	-11522.4	144
5	1989	880.3	-11	-9683.3	121
6	1990	988.1	-10	-9881	100

7	1991	594.6	-9	-5351.4	81
8	1992	642.8	-8	-5142.4	64
9	1993	808.2	-7	-5657.4	49
10	1994	1013.7	-6	-6082.2	36
11	1995	656.6	-5	-3283	25
12	1996	893.4	-4	-3573.6	16
13	1997	808.8	-3	-2426.4	9
14	1998	821.2	-2	-1642.4	4
15	1999	489.5	-1	-489.5	1
16	2000	420.48	0	0	0
17	2001	541.9	1	541.9	1
18	2002	761.1	2	1522.2	4
19	2003	834.2	3	2502.6	9
20	2004	678.4	4	2713.6	16
21	2005	525.4	5	2627	25
22	2006	1288.2	6	7729.2	36
23	2007	870	7	6090	49
24	2008	730	8	5840	64
25	2009	722.2	9	6499.8	81
26	2010	746.86	10	7468.6	100
27	2011	707.3	11	7780.3	121
28	2012	579.5	12	6954	144
29	2013	1043.7	13	13568.1	169
30	2014	742.2	14	10390.8	196
31	2015	786.7	15	11800.5	225
Total		$\Sigma Y=23027.64$	$\Sigma X=0$	$\Sigma XY=8432.4$	$\Sigma X^2=2480$

Table 6: Computation of expected rainfall of the Barwani study are, Barwani district, Madhya Pradesh, India.

S. No.	Years	Expected Rainfall (mm.)
1	2016	797.2
2	2017	800.6
3	2018	804.0
4	2019	807.4
5	2020	810.8
6	2021	814.2
7	2022	817.6
8	2023	821
9	2024	824.4
10	2025	827.8

The future trend of expected rainfall up to period of 2025 in the study area has been displayed in Figure 6. The expected rainfall trend is positive.

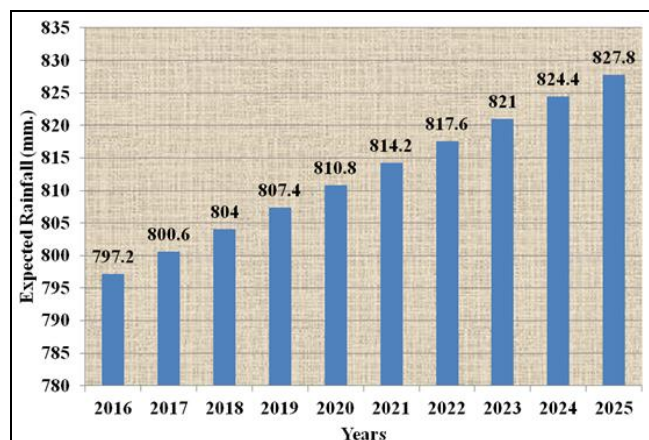


Fig 6: Future trend of expected rainfall up to period of 2016-2025 in the Barwani Study Area, Madhya Pradesh, India

Environmental Impacts

Rainfall pattern plays an important role in the recharge phenomena of ground water system. The rainfall data analysis of Barwani area indicates a fairly good range of variation indicating both the positive and negative trends, which affect the recharge of the ground water system. The present trend of over exploitation and scanty rainfall is resulting into depletion of the ground water levels. Todd (1980) [11] remarked that ground water levels may show seasonal variation due to rainfall. Drought extending over period of several years, contribute to declining water levels. The recharge phenomena of ground water can be improved by increasing the rainwater. It is suggested that implementation of appropriate measures will provide remedy in reducing the rapidly rising condition of ground water level depletion resulting in the drought conditions in Barwani area. The increase in amount and frequency of rainfall is required to enhance the recharge phenomena of the ground water system of Barwani area. The scheme of augmentation of rainfall involves the implementation of rainwater harvesting and a forestation.

Conclusion

The rainfall data have been subjected to mathematical and statistical analysis. The mathematical analysis determines a variation trend of rainfall data that indicates range from 420.4 mm. to 1288.1 mm. and annual average value of rainfall as 742.8 mm. It has been observed that the rainfall departure from the average rainfall was of higher value during the years of 1988-1990, 1993, 1994, 1996-1998, 2002, 2003, 2006, 2007, 2013 and 2015. The years indicating higher values of departure from the average rainfall revealed favorable period for recharge of rainwater to the ground water storage. The annual departure from the average during the years of 1985-1987, 1991-1992, 1995, 1999-2001, 2004-2005, 2008-2012 and 2014 reveal rainfall amount lower the average annual

rainfall. The years of low rainfall point out a negative trend which causes reduction in the ground water levels in the study area. The statistical analysis for rainfall data points out determination of Mean (735.48 mm.), Median (750 mm.), Mode (775 mm.), Standard Deviation (192.64 mm.), Coefficient of Dispersion (0.261), Co-efficient of Variation (26.19), and Coefficient of Skewness (-0.205). The determined values of statistical parameters indicate a negative trend of rainfall. The impacts of rainfall variation in recharge phenomena of groundwater system have been discussed in this paper.

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