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# Analysis of rainfall data, prediction of trend and environmental impacts on ground water system recharge of Meghnagar area, Jhabua district, Madhya Pradesh, India

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**Abstract**
The paper incorporates results of rainfall data analysis for 26 years (1990-2015), the prediction of rainfall trend and environmental implications on the ground water system recharge of the Meghnagar area located in Jhabua district of Madhya Pradesh, India. The rainfall data have been sunjected to both the mathematical and statistical analyses and the environmental impacts on the ground water system recharge have been discussed.
Mathematical analysis of rainfall data indicates a fairly good variation range from 380 mm (1992) to 1509.mm (2006) with an average of 873.14 mm. The annual departure with respect to average value indicates the nature of both positive and negative recharge trend of ground water reservoir. The cumulative departure indicates a trend of increase and decrease in the rain water to ground water system. The statistical treatment of rainfall data reveals the value of Mean = 892.31 mm, Median = 950 mm, Mode = 800 mm, Standard Deviation = 329.14, Co-efficient of dispersion = 0.368, Co-efficient of variation = 36.88, Co-efficient of skewness = 0.280 the statistical treatment of rainfall data provides precise values indicating the nature of recharge trend.
Based on time series analysis, an attempt has been made to determine the trends of expected annual rainfall in coming years. The analysis of rainfall data points out that higher rainfall amount than the annual average value is indicating the period of favourable recharge to ground water system, whereas, lower values than the average value point out the negative trend of recharge that reflects the shortage of water supply to the ground water system,, and a few times, even resulting into drought condition. The rainfall is most important hydrometreological factor that controls the nature of the ground water reservoir. The rainfall factor is also influencing the environmental scenario of development of the society, forest, agriculture and vegetation.

**Keywords:** Analysis, Rainfall, Prediction trend, Environmental impacts, Ground water System, Meghnagar, 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 ground water 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 elements 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) [10, 11, 9, 7]. According to Fetter (1988, 1990) [5-6] the atmosphere moisture may be precipitated either as solid or liquid states. The rainfall is measured by means of rain gauges. The recorded values are expressed in inch or mm. The rainfall records revels a wide range of variation in the amount and frequency data of rainfall are important factor that control the surface runoff for the ground water recharge. Nigwal and Dev (2014) [8] published a paper on the rainfall data of 20 years (1002–2011) analysis and environmental impacts on ground water resource of Meghnagar area. The present paper deals with the results of rainfall data (1990–2015) analysis, prediction of future trend and environmental impacts on the ground water system of Meghnagar area, Jhabua district, Madhya Pradesh.

## Concept of Rainfall
Rainfall is one of the most important meteorological parameter, which plays a vital role in the recharge of ground water system. Rainwater or rainfall is a liquid form of the "precipitation" that acts as a primary significant source for the recharge of ground water system of a particular area. It also plays an important role in the estimation of water balance of a particular basin. 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 (Wiesner, 1970) [12]. The rainwater or rainfall is recorded through rain gauges. In India, Semen's rain gauge is frequently used for recording rainfall data. The recorded values are expressed in inch or mm. Rainfall records indicate a wide range of variation in the amounts and frequencies from place to place. The duration and frequency of rainfall event affect the surface runoff for the ground water recharge.
In India, rainfall mostly occurs during the monsoon period (Mid. June to September). Dhar and Rakhecha (1975) [4] have

reviewed the hydrometrological studies of Indian rainfall. In the present study, an attempt has been made to analyze the rainfall data of Meghnagar area to visualize the environmental impacts on the recharge of ground water system. The results of variation analysis of rainfall data for a period of 1990 to 2015 collected from the Jhabua District Office of Madhya Pradesh are displayed. Environmental impacts of rainfall factor on the recharge of ground water reservoir have been discussed.

**Rainfall Data Analysis and Inter -Pretation**

The collected annual rainfall data of Meghnagar area for a period of 26 years (1990 to 2015) have been displayed (Table 1). The rainfall data have been subjected to both the methods of mathematical and statistical analysis.

**Table 1:** Annual rainfall data, its departure and cumulative departure from the annual average rainfall in study area (1990-2015). Values are expressed in mm.

| S.N. | Years | Total rainfall of the year | Departure form average rainfall | Commutative departure form average rainfall |
|---|---|---|---|---|
| 01 | 1990 | 1281.0 | 407.86 | 407.86 |
| 02 | 1991 | 707.0 | -166.14 | 241.72 |
| 03 | 1992 | 380.0 | -493.14 | -251.42 |
| 04 | 1993 | 1122.0 | 248.86 | -2.56 |
| 05 | 1994 | 1132.5 | 259.36 | 256.8 |
| 06 | 1995 | 614.8 | -258.34 | -1.54 |
| 07 | 1996 | 963.5 | 90.36 | 88.82 |
| 08 | 1997 | 942.4 | 69.26 | 158.08 |
| 09 | 1998 | 981.0 | 107.86 | 265.94 |
| 10 | 1999 | 458.0 | -415.14 | -149.2 |
| 11 | 2000 | 510.0 | -363.14 | -512.34 |
| 12 | 2001 | 495.0 | -378.14 | -890.48 |
| 13 | 2002 | 641.0 | -232.14 | -1122.62 |
| 14 | 2003 | 1320.0 | 446.86 | -675.76 |
| 15 | 2004 | 1196.0 | 322.86 | -353.9 |
| 16 | 2005 | 826.0 | -47.14 | -400.04 |
| 17 | 2006 | 1509.0 | 635.86 | 235.82 |
| 18 | 2007 | 1180.0 | 306.86 | 542.68 |
| 19 | 2008 | 608.0 | -265.14 | 277.54 |
| 20 | 2009 | 629.0 | -244.14 | 33.4 |
| 21 | 2010 | 713.0 | -160.14 | -126.74 |
| 22 | 2011 | 1191.0 | 317.86 | 191.12 |
| 23 | 2012 | 990.5 | 117.36 | 308.48 |
| 24 | 2013 | 1103.0 | 229.86 | 538.34 |
| 25 | 2014 | 668.0 | -205.14 | 333.20 |
| 26 | 2015 | 540.0 | -333.14 | 0.06 |
| Total | | | 22701.70 | |
| Average Rainfall | | | 873.14 | |

**Mathematical Analysis**

The arithmetic method is generally employed for the analysis of rainfall data. The analysis involves calculation of the average for the period of specific months or years as arithmetic mean. The calculated values are recorded in mm. cm or inch. The variation in rainfall is indicated by a stable mean generally, a rainfall record of 20 to 50 years is used for the computation of arithmetic mean The rainfall data of Meghnagar area indicates a variation range from 380 mm to 1509 mm. The minimum rainfall has been noted during (1992). The maximum annual rainfall has been observed during 2006. The mathematical analysis reveals annual average rainfall value as 873.14 mm. (Table 1, Fugure 1).

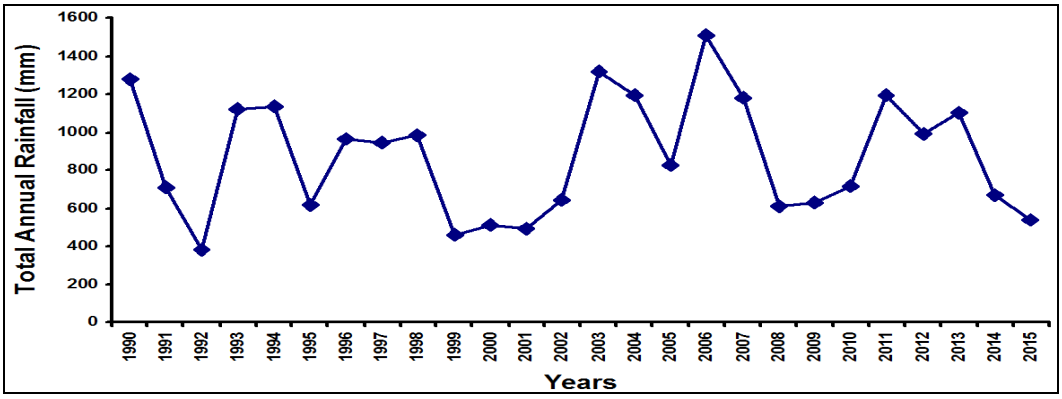


**Fig 1:** Total Annual Rainfall (mm) for the period 1990 -2015

The departure from annual average rainfall for the years of 1990 to 2015 (Table 1, Figure 2). The plots of more than the average rainfal during 1990, 1993 - 1994, 1996 – 1998, 2003 - 2004, 2006,- 2007, and 2011 - 2013 indicate positive trend of recharge and plots of rainfall less than average value during the years of1991, 1992, 1995, 1999, 2000 - 2002, 2005, 2008 – 2010, and 2014 - 2015 point out negative trend of rainfall on the ground water system. (Figure 3)

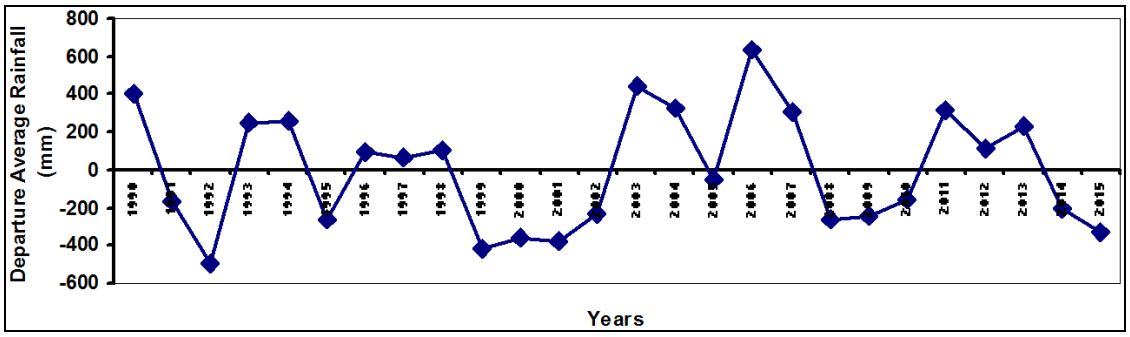


**Fig 2:** Departure from Average Rainfall for the period 1990 to 2015

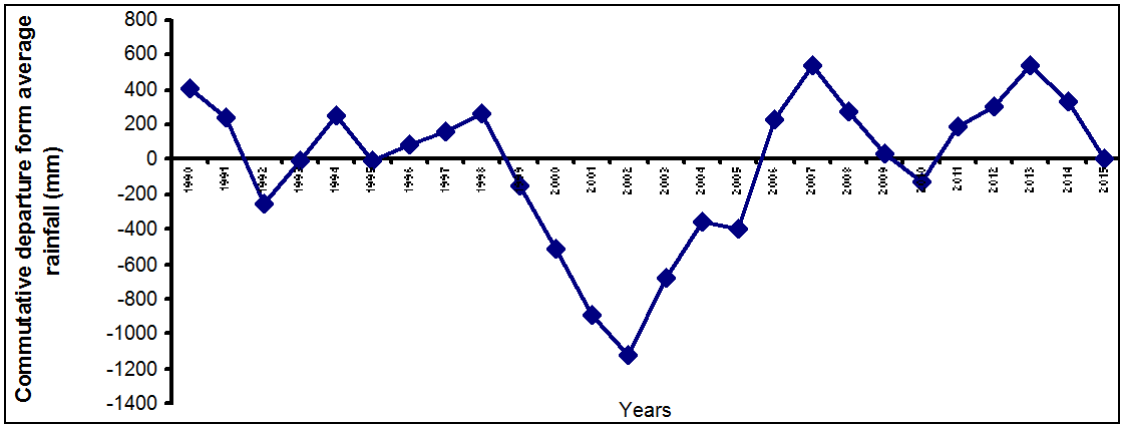


**Fig 3:** Commutative departure from Average Rainfall for the period 1990 to 2015.

**Statistical Analysis**

The procedures of the computation of statistical parameters suggested by Davis (1986, 2002) [2-3] have been adopted in the present text: The calculations of central tendencies ((mean median and mode), and parameters such as standard deviation,, coefficient of dispersion,, coefficient of variation, coefficient of skewness, and time series analysis have been conducted. The method of time series analysis suggested by Croxton *et al*. (1988) [1]. Has been followed. The time series analysis enables essential information regarding the trend of a series of observations. It helps to measure the deviation from the trend and also reveals the nature of trend. Time series analysis is used as a tool to predict the performance of the future trend.

The method of least square fit of straight line has been emploted for per forming the trend analysis of the trend analysis of the behavior of yearly rainfall. A time series determines a tendency to increase or decrease, over a specified episode. 'This series provides an interesting illustration because the trend is usually predominant, virtually no other movement is discernable' (Croxton *et al,* 1988) [1]. The rainfall data of Meghnagar area have been classified into seven groups (Table.2) and various statistical parameters were computed.

**Table 2:** Frequency distribution analysis of rainfall data of Meghnagar area, Jhabua, M. P.

| Class Interval | Mid Value (X) | Frequency (f) | μ | f x μ | $\mu^2$ | f x $\mu^2$ | Cumulative Frequency |
|---|---|---|---|---|---|---|---|
| 300-500 | 400 | 3 | -3 | -9 | 9 | 27 | 3 |
| 500-700 | 600 | 7 | -2 | -14 | 4 | 28 | 10 |
| 700-900 | 800 | 3 | -1 | -3 | 1 | 3 | 13 |
| 900-1100 | 1000 | 4 | 0 | 0 | 0 | 0 | 17 |
| 1100-1300 | 1200 | 7 | 1 | 7 | 1 | 7 | 24 |
| 1300-1500 | 1400 | 1 | 2 | 2 | 4 | 4 | 25 |
| 1500-1700 | 1600 | 1 | 3 | 3 | 9 | 9 | 26 |
| Total | 7000 | 26 | 0 | -14 | 28 | 78 | 118 |

**Mean**

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

$$\text{Mean} = A + (I \, x \sum f\mu) / N$$

Where

A = Assumed mean = 1000
I = Class interval = 200
Fu = Frequency = -14
N = total frequency = 2

Mean; = 1000 = [200(-14)]/26
= 1000 – 107.69
= 892.31 mm

**Median**

Median for a set of observations is the variable, which divided it into two equal parts. It is calculated by the formula

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

Where,

L = lower limit of median class = 90
F = Frequency of median class = 4
I = Magnitude of median class = 200
C = cumulative frequency of the median class preceding = 1

Median = 900 + 200/4 (13 – 13)
= 900 + 50 (0)
= mm950.

**Mode**

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

$$\text{Mode} = l + [i(f_1 - f_0)]/[2f_1 - f_0 - f_2]$$

Where

L = lower limit of model class = 900
I = class interval = 200
F = Frequency of model class = 4
$f_0$ = Frequency of class preceding the modal class= 3
$f_2$ = Frequency of class succeeding the modal class= 7

Mode = 900 + [200(4-3)] / [2x4-3-7]
= 900 + (-100)
= 800 mm

**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 determined by use the following formula.

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

Where

$\sigma$ = Standard deviation
N = total frequency = 26
i = class interval = 200
$fu^2$ = 78= -14

$$200 / 26\sqrt{26}\, x\, 78 - (-14)^2$$
$$= 7.69\sqrt{1832}$$
$$= 329.14$$

**Co-Efficient of Dispersion**

The co-efficient as dispersion deals with the measurement and is calculated by following expression

C.D = Standard Deviation /Mean

Where

S.D = 329.14, Mean = 892.31
C.D = 329.14/892.31
= 0.368

**Co-Efficient of Variatio N**

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

Co-efficient of variation (CV) = 100 x (standard deviation)/mean
Mean = 892.31
Standard deviation (Sd) = 329.14
= 100 x (329.14)/892.31
= 36.88

**Co-efficient of Skewness**

It demotes lack of symmetry in the given distribution and is computed by using the formula

Co-efficient of skewness = (Mean – Mode) / standard deviation
Mean = 892.31
Mode = 800
Standard deviation = 329.14
Co-efficient of skewness = (892.31-800) / 329.14
= 0.280

**Time Series Analysis**

The time series analysis generates valuable information's regarding the trend of a series of 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 behaviour 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

Yc = a + bx
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.

$$\sum y = Na + b\sum y \quad \text{.....(1)}$$
$$\sum xy = a\sum x + b\sum x^2 \quad \text{.....(2)}$$

The values of the various elements in the above equations have been determined by considering "Y" as variable (annual rainfall) and "X" as constant (year)

The determinations were made as per the procedure described below-

N = 26, Σ x = 13, Σ y =22701.7
$\Sigma x^2$ =1469 = Σxy =11957.4

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

$22701.7 = 26\ a + 13\ b$ ..... (3)
$11957.4 = 13\ a + 1469\ b$ ..... (4)

Solving equations (3) and (4) the values of a and b are obtained as 4.147 and 871.06 respectively.

**Table 3:** Time series Analysis of Rainfall data of Meghnagar area Jhabua district M. P.

| Year | (x) | (rainfall (y) mm | ($x^2$) | (xy) | Trend value |
|---|---|---|---|---|---|
| 1990 | -12 | 1281.0 | 144 | -15372 | 821.29 |
| 1991 | -11 | 707.0 | 121 | -7777 | 825.44 |
| 1992 | -10 | 380.0 | 100 | -3800 | 829.59 |
| 1993 | -9 | 1122.0 | 81 | -10098 | 833.73 |
| 1994 | -8 | 1132.5 | 64 | -9060 | 837.88 |
| 1995 | -7 | 614.8 | 49 | -4303.6 | 842.03 |
| 1996 | -6 | 963.5 | 36 | -5781 | 846.17 |
| 1997 | -5 | 942.4 | 25 | -4712 | 850.32 |
| 1998 | -4 | 981.0 | 16 | -3924 | 854.47 |
| 1999 | -3 | 458.0 | 9 | -1374 | 858.61 |
| 2000 | -2 | 510.0 | 4 | -1020 | 862.76 |
| 2001 | -1 | 495.0 | 1 | -495 | 866.91 |
| 2002 | 0 | 641.0 | 0 | 0 | 871.06 |
| 2003 | 1 | 1320.0 | 1 | 1320 | 875.20 |
| 2004 | 2 | 1196.0 | 4 | 2392 | 879.35 |
| 2005 | 3 | 826.0 | 9 | 2478 | 883.50 |
| 2006 | 4 | 1509.0 | 16 | 6036 | 887.64 |
| 2007 | 5 | 1180.0 | 25 | 5900 | 891.79 |
| 2008 | 6 | 608.0 | 36 | 3648 | 895.94 |
| 2009 | 7 | 629.0 | 49 | 4403 | 900.08 |
| 2010 | 8 | 713.0 | 64 | 5704 | 904.23 |
| 2011 | 9 | 1191.0 | 81 | 10719 | 908.38 |
| 2012 | 10 | 990.5 | 100 | 9905 | 912.53 |
| 2013 | 11 | 1103.0 | 121 | 12133 | 916.67 |
| 2014 | 12 | 668.0 | 144 | 8016 | 920.82 |
| 2015 | 13 | 540.0 | 169 | 7020 | 924.97 |
| | Ex = 13 | 22701.7 | $Ex^{2=}$ 1469 | 11957.4 | |

Hence a equation of straight line is obtained and it is written as

$$Ye = 871.06 + 4.147\ (x) \quad ..... (5)$$

With the help of equation (5) the trend values have been computed in Table.3. The future forecast of rainfall amount for a period of six years from 1990 to 2015 has been made as per the procedure listed below

Y 2016 = 871.06 + 4.147 x 15 = 933.265 mm.
Y 2017 = 871.06 + 4.147 x 16 = 937.412 mm.
Y 2018 = 871.06 + 4.147 x 17 = 941.559 mm.
Y 2019 = 871.06 + 4.147 x 18 = 945.706 mm.
Y 2020 = 871.06 Y 2 + 4.147 x 19 = 949.853 mm.
Y 2021 = 871.06 + 4.147 x 20 = 954 mm.

The calculated trend values of rainfall for the year 2016 = 933.265, 2017 = 937.412, 2018 = 941.559, 2019 = 945.706, 2020 = 949.853, 2021 = 954.

**Environmental Impacts**

The rainfall factor plays a controlling role on the ground water recharge phenomena. The rainfall data analysis of Meghnagar study area indicates a fairly good range of variation pointing out both the positive and negative trends which affect the recharge of the ground water reservoir. The present trend of over exploitation and scanty rainfall are cousing rapid depletion in the ground water levels. Todd (1980) [11] remarked that ground water levels may show seasonal variation due to rainfall draught extending over a period of several years, contribute to declining water levels have been ascribed to seasonal variations in the static ground water levels, which are affected by infiltration of rainwater. This process is dependent on the amount and intensity of rainfall.

The recharge phenomena of ground water can be improved by augmentation of rainwater. It is suggested that implementation of suitable measures may provide remedy in minimizing the rapidly developing situation of ground water level depletion which is resulting in the drought conditions in Meghnagar area.

**Conclusion**

The rainfall dada analyses of Meghnag har area for a pairad of 26 years provid valuable data information such as the variation trends of rainfall amound and the trend of the recharge of ground water system. The relationship of the anuval rainfall and its departure from the annual average

rainfall, and ther impacts on the ground water systam. Based on the time series analysis of statistical parameters of rainfall data an attemept the future trend of rainfall has been made to predict the future trend of rainfall. The environmental impact analysis of rainfall factor on the ground water system have been decribed. It has been observed that the rainfall governs the recharge phenomena of the ground water system.

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