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A Study on Impact of Rainfall Trend on Ground Water Recharge and Environment of Datana – Palkhanda Area, of Ujjain District, Madhya Pradesh, India

[1]Dr. Arti Dawar and [2]Dr. Pankaj Barbele*

Author's Affiliations:
[1]Assistant Professor, Department of Earth Science, Barkatullah University, Bhopal, Madhya Pradesh 462026, India.
[2] Geologist, House No. 45/2 Fazal Pura Near Baba Ram Dev Temple, Ujjain, Madhya Pradesh, India

***Corresponding Author:** Dr. Pankaj Barbele, Geologist, House No. 45/2 Fazal Pura Near Baba Ram Dev Temple, Ujjain, Madhya Pradesh, India
E-mail: barbelepankaj@gmail.com, daarti7@gmail.com
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Abstract:
This Paper concerns with the analysis of rainfall data and environmental impacts of rainfall factor on ground water system of Datana – Palkhanda, Ujjain District of Madhya Pradesh. The rainfall is an important hydro-meteorological parameter, which plays an important role in recharge of the ground water reservoirs. The rainfall data of the area have been analyzed by using both the mathematical and statistical methods. The available records of rainfall data for a period of 31 years (1985-2015) in respect of Ujjain study area have been analyzed and displayed by both the tabular and graphic methods of representation. The mathematical analysis of rainfall data reveals a variation range from 472.5 to 2019 mm, with an average of 1010.8 mm. The recorded rainfall more than the average rainfall value, indicate that during the years of 1990, 1993, 1994, 1995, 1996, 1997, 1998, 2003, 2006, 2007, 2009, 2010, 2012, 2013, 2015, the rainfall trends were positive, reflecting favourable period for the ground water recharge. The minimum rainfall of the study area has been recorded during the years of 1985, 1987, 1989, 1991, 1992, 1999, 2000, 2001, 2002, 2004, 2005, 2008, 2011 and 2014. These years indicate that the rainfall was unfavourable for sufficient infiltration of the rain water to the ground water storage. The statistical analysis of rainfall data has determined parameters such as mean (1022.58 mm), median (1012.50 mm) and mode (1020.00 mm), standard deviation (300.52), coefficient of dispersion (0.29), coefficient of skewness (0.008), and coefficient of variation (29.38). The rainfall data analysis of the Ujjain study area indicates a fairly good range of variations indicating the irregular positive and negative values as compared to the average annual rainfall. The forecast of expected future rainfall for a period of next five years indicate a positive trend as compared to the annual average rainfall amount. The environmental impacts of rainfall phenomena have also been discussed.

Keywords: *Environmental impact, Rainfall, Recharge, Ground water system, Datana – Palkhanda, Ujjain, Madhya Pradesh, India.*

INTRODUCTION

Rainfall is most significant meteorological factor, which plays a principal role on the recharge of sub-surface water (ground water system) of a geographic area or a basin. The rainfall is a general expression for the precipitation factor of the hydrological cycle. Wiesner (1970) has defined rainfall as "The depositing of water from the atmosphere on to a surface. These deposits may be either liquid or solid to give the various form of precipitation" Navarra, (1979), considered that "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." Rakhecha and Singh (2009) defined the term Rainfall as the primary source of water that occurs as a result of the condensation of atmospheric moisture, which is governed by the science of metrology and therefore, it is considered to be one of the most important meteorological elements. The rainfall occurs in a number of forms such as rain, drizzles, snowflakes, snow, freezing rain, and hail.

MEASUREMENT OF RAINFALL

Rainfall is calculated with the assistance of Rain Gauge, which measures the amount of rain over a fixed time (Garg, 1979). There are two types of rain gauges (i) Recording rain gauge ((ii) The non-recording rain gauge.

A. Non recording gauge

Non recording gauge is this type of rain gauge that does not record the rain but it only collects the rain. The collected rain is then measured by means of graduated cylinders at regular intervals, commonly of 24 hrs., a week or a month and directly represent the rainfall volume is cm of water depth. Non recording gauges of various models have been designed for such gauges like Symon's type, which is mainly used in India.

B. Recording gauges

Recording type rain gauges are those rain gauges which can give us a permanent automatic rainfall record. The recording type gauge is also known as automatic, self-recording, or integrating rain gauges. This type of gauge provides automatic rainfall record on a graph paper, which may be an hour, a day, a month, a year. The gauge thus produces a record of cumulative rain against time in the form of a graph that is recognized as mass curve of rainfall. Recording gauge models includes the tipping bucket type, weighing type, floating type etc. The rainfall measurements are generally recorded on the principle of Symon's pattern of rain gauge.

RAINFALL STATUS IN INDIA

In India, the rainfall is predominantly governed by the monsoon climate. The monsoon in India arises from the U-turn of prevailing wind direction from South- West to North-East and results in the distinct season during the course of the year. The South-West monsoon brings heavy rains over most of the country during middle of June to September and is commonly referred as the 'wet' season. Moisture loaded winds sweep in from the Indian Ocean as low-pressure areas developed over the subcontinent and release their moisture in the form of heavy rainfall. Most of the annual rainfall in India comes during monsoon period whereas the Tamil Nadu receives over half of its rain during the North-East monsoon from October to November.

Rainfall infiltration gives most essential spring of ground water recharge. In India, the majority of the ground and surface water recharge occur during the monsoon season. Recharge in the middle of winter and summer seasons are fairly less or immaterial. Rock formations met within upper layers of earth are normally, considered as basis for separating a nation in different regions for expecting level of rainfall infiltration (Nagabhushaniah, 2001). Rainfall period is essentially for the period of June to September in India with an average estimation of rainfall as 936.7 mm (India Meteorological Department, 2013).

ANALYSIS OF RAINFALL DATA

The examination of rainfall data is very difficult for the reason that rainfall depends upon two imperative elements of time and space. Mathematic and Statistical techniques are utilized for the test of rainfall data. The most broadly followed procedure for rainfall data analysis is Mathematical method. In Mathematic procedure, the normal rainfall for a time of year or month is specified by arithmetic mean for the time of the years. Statistical method provides précised values and validity of Mathematical analysis. The procedures of statistical analysis have been given by number of workers. The generally utilized methods of statistical examination have been adopted by Gupta and

Kapoor (1986), Croxton *et, at.* (1988), Davis (2002) and others (Table 2).

In the present work, rainfall data of the last 31 years (1985-2015) in respect of Ujjain study area have been collected from the Ujjain District Collectorate Office, and are displayed herein (Table 1). The analysis of data has been described in the text.

Table 1: Annual Rainfall, Departure and cumulative Departure from Average Annual Rainfall in the study area.

Sr. No.	Year	Total Rainfall (m.m.)	Departure from Average rainfall	Cumulative departure from average rainfall
1	1985	472.4	-537.6	83.1
2	1986	1253.6	-528.1	-445
3	1987	862.7	253.1	-191.9
4	1988	976.4	-137.8	-329.7
5	1989	750.6	-24.1	-353.8
6	1990	1211.6	-249.9	-603.7
7	1991	918.8	211.1	-392.6
8	1992	631.4	-81.7	-474.3
9	1993	1258.0	-369.1	843.4
10	1994	1250.3	257.5	-585.9
11	1995	1118.4	249.8	-336.1
12	1996	1266.1	117.9	-218.2
13	1997	1049.0	265.6	47.4
14	1998	1013.0	48.5	95.9
15	1999	960.8	12.5	108.4
16	2000	970.0	-39.7	68.7
17	2001	570.0	-30.5	38.2
18	2002	810.6	-430.5	-392.3
19	2003	1012.4	-189.9	-582.2
20	2004	861.8	11.9	-570.3
21	2005	563.8	-138.7	-709
22	2006	2019.0	-436.7	-1145.7
23	2007	1393.5	1018.5	-127.2
24	2008	723.0	393	265.8
25	2009	1097.0	-277.5	-11.7
26	2010	1126.8	96.5	84.8
27	2011	730.4	126.3	211.1
28	2012	1069.5	-270.1	-59
29	2013	1329	69	10
30	2014	661.7	328.5	338.5
31	2015	1405.2	-338.5	0
	Total	31337.1	Average rainfall = 1010.86 mm.	

Mathematical Method

The total yearly rainfall data for a time period of 31 years (1985-2015) have been recorded (Table 1). The lowest amount of rainfall has been recorded as 472.5 mm for the period of 1985 and highest rainfall has been observed as 2019 mm during the year of 2006. The normal yearly rainfall of the region has been figured as 1010.86 mm. The departure and cumulative departure from the normal annual rainfall of the study area are shown (Table 1).

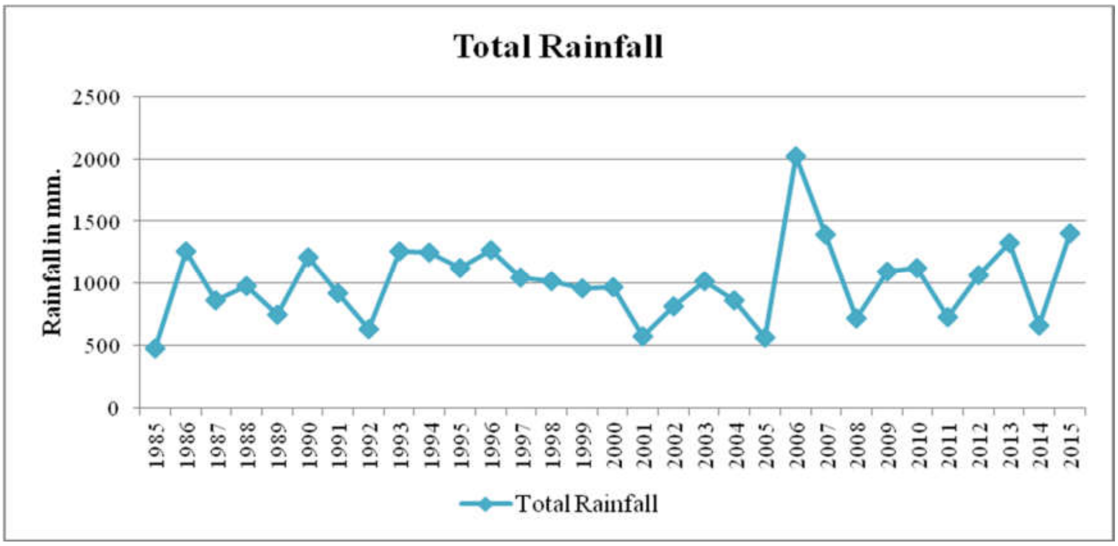

Figure 1 Showing total rain fall (in mm) for the period of 1985-2015.

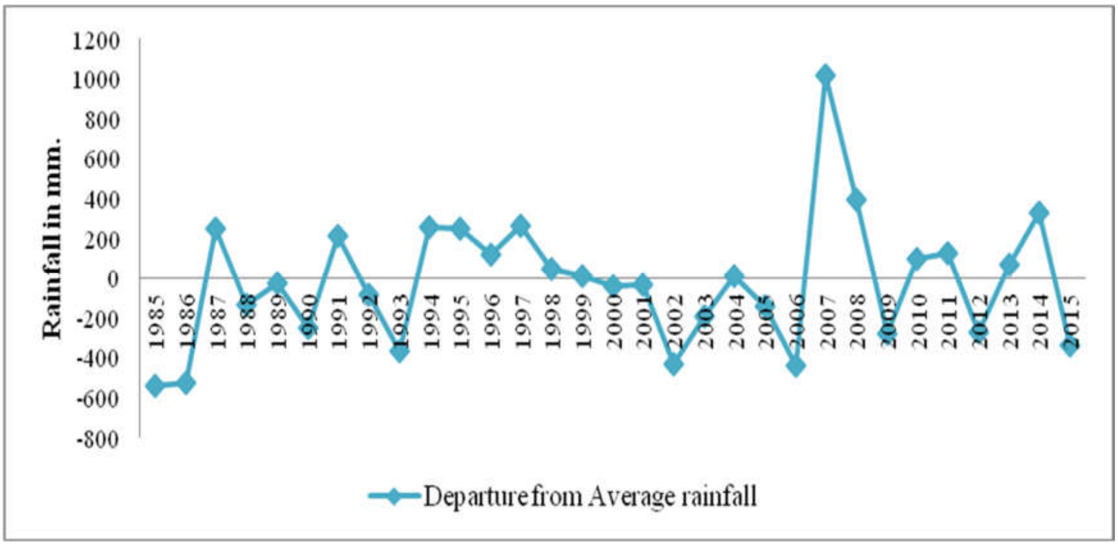

Figure 2 Showing departures from average rainfall for the period of 1985-2015

Departure and cumulative departure from the normal yearly rainfall have been worked out, and displayed (Table 1), and the trend of rainfall has been graphically represented (Figure 2,3). The values of rainfall departure exceeding average rainfall values have been recorded during the years 1984, 1986, 1990, 1993, 1994, 1995, 1996, 1997, 1998, 2003, 2006, 2007, 2010, 2012, 2013. The value of cumulative departure from the normal annual rainfall value exhibits that the highest rainfall peak is observed in year of 1998 in this way taken after continuously 1997, 1996, 1999, 2000, 2007, and 1984. The higher peaks reveal genuinely immense infiltration of rain water to ground water storage. These years are favourable for ground water recharge.

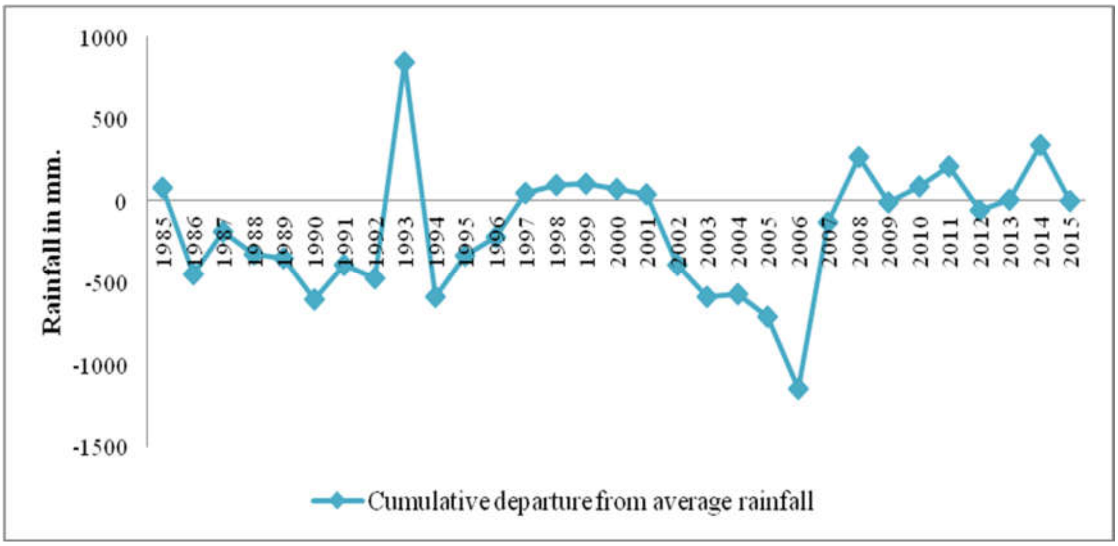

Figure 3: Showing cumulative departures from average rain fall for the period of 1985-2015

The lowest amount of rainfall of the present study area has been noted for the period of 1985, 1987, 1989, 1992, 2001, 2002, 2005, 2008, 2011 and 2014. Rainfall was above than the normal rainfall of the present study area reveals that in the years of 1984, 1986, 1990, 1993, 1994, 1995, 1996, 1997, 1998, 2003, 2006, 2007, 2009, 2010, 2012, 2013, 2015 and the highest rainfall peak was observed for the period of 2006 (Figure 3).

Statistical Method

The term statistics has been defined as, "the series which deals with the collection, analysis and interpretation of numerical data" (Croxton and Cowden, 1988). According to Sarkar (2004) Statistics is "a branch of applied mathematics dealing with science or perhaps an art of the collection, presentation, description, inference, significance testing and prediction of numerical information". Recently, Caers (2005) has considered that Geostatistics as "a branch of statistical sciences that studies spatial/temporal phenomena and capitalizes on spatial relationships to model possible values of variable(s) at unobserved, unsampled locations".

The statistical method has been used for the analysis of rainfall data for a period from 1985 to 2015 incorporates determinations of central tendencies (Mean, Median, Mode) and other different parameters. The variables of rainfall data for the statistical analysis are displayed (Table 2), the frequency distribution and cumulative frequencies have been worked out for 9 classes of rainfall data. The other statistical parameters such as Standard Deviation, Coefficients of dispersion, variation, and skewness have been determined.

Table 2: Computation of statistical variable of rainfall data, Ujjain district (M.P.)

Class interval	Mid value(x)	Frequency (f)	Cumulative frequency (C)	d=(x-A)/i	Fxd	d²	fxd²
400-600	500	3	3	-4	-12	16	48
600-800	700	5	8	-3	-15	9	45
800-1000	900	7	15	-2	-14	4	28
1000-1200	1100	7	22	-1	-7	1	7
1200-1400	1300	7	29	0	0	0	0
1400-1600	1500	1	30	1	1	1	1

1600-1800	1700	0	30	2	0	4	0
1800-2000	1900	0	30	3	0	9	0
2000-2200	2100	1	31	4	4	16	1
Total		**N = 31**			**∑fd = -43**		**∑f d² = 130**

The central tendencies include Mean, Median and Mode. The methods of calculation of these parameters are described below:

Mean

Arithmetic mean of a series is the number obtained by dividing the total values of various items by their number. The mean in another word for arithmetic normal and is characterized as the total of all perception isolated by the quantity of perceptions.

$$Mean = A + \frac{i \times \sum fd}{N}$$

Where,

A= the Assumed mean

I= the class interval

N = sum of frequency

In computed rainfall parameters are A = 1300, i = 200, N = 31, ∑fd = -43

Hence,

$$\text{Mean} = A + \frac{i \times \sum fd}{N}$$

$$\text{Mean} = 1300 + \frac{200 \times (-43)}{31}$$

Mean = 1022.58 mm.

Median

The median is an estimation of variable, which isolates the gathering into two equivalent amounts of one section containing all qualities more prominent, and all other qualities less than the median.

$$Median = L + \frac{i}{f}\left(\frac{N}{2} - C\right)$$

Where,

L is the lower limit of median class

i is the Magnitude of the median class interval

f is the frequency of median class

C is the Cumulative frequency of class preceding the median class.

In the Ujjain region, computed rainfall parameters are *L = 1000, i = 200, f =8, C = 15*

Hence,

$$Median = L + \frac{i}{f}\left(\frac{N}{2} - C\right)$$

$$= 1000 + \frac{200}{8}\left(\frac{31}{2} - 15\right)$$

Median = 1012.5 mm.

Mode

Croxton and Cowden (1988) considered that the method of an appropriation is the qualities at the point furnished with the thing keep an eye on most intensely focused. It might be viewed as the most common place of a progression of significant worth. The accurate estimation of mode can be achieved by the procedure as:

$$Mode = L + \frac{i\,(f_1 - f_0)}{2f_1 - f_0 - f_2}$$

Where,

L is the lower limit of modal class

i is class interval

f_1 is frequency of modal class

f_0 is frequency of class proceeding the modal class.

f_2 is frequency of class succeeding the modal class.

In the present study area, computed rainfall parameters are *L = 1000, i = 200,* $f_1 = 7, f_0 = 5, f_2 = 7$

Hence,

$$Mode = L + \frac{i\,(f_1 - f_0)}{2f_1 - f_0 - f_2}$$

$$Mode = 700 + \frac{200\ (7 - 5)}{(2 \times 7) - 5 - 8}$$

Mode = 1100 mm.

Standard deviation

Standard deviation is a proportion of the optimistic square of arithmetic mean of square of deviation of given qualities from their arithmetic mean. It is considered by the formula given beneath:

$$\sigma = i \sqrt{\left\{ \frac{1}{N} \sum fd^2 - \left(\frac{1}{N} \sum fd \right)^2 \right\}}$$

Where,
i is the class interval
N is sum of frequency
In the study area, computed rainfall parameters are i= *200, N = 31, ∑fd = -43,* $\sum fd^2=130$
Hence,

$$\sigma = i \sqrt{\left\{ \frac{1}{N} \sum fd^2 - \left(\frac{1}{N} \sum fd \right)^2 \right\}}$$

$$\sigma = 200 \sqrt{\left\{ \frac{1}{31} \times 130 - \left(\frac{1}{31} \times (-43) \right)^2 \right\}}$$

Standard deviation mm = 300.52

Co-efficient of Dispersion
Correlation of fluctuation of two arrangements, that varies normally in their midpoints. The co-efficient of dispersion is complete number autonomous of the units of estimation. It is computed by the expression:
Co-efficient of Dispersion = Standard deviation / Mean
In the study area, computed rainfall parameters are
Mean = 1022.58 mm,
Standard deviation = 300.52 mm.
Hence,
Co-efficient of dispersion = Standard deviation / Mean
Co-efficient of dispersion = 300.52 / 1022.58
Co-efficient of Dispersion = 0.2938

Co-efficient of Variation
Coefficient of variation has been characterized as the rate variety in the Mean and Standard Deviation is considered as the aggregate variety in the mean. It is dictated by the accompanying articulation.
Co-efficient of Variation = 100 x Co-efficient of dispersion
In the study area, computed rainfall parameters are
Co-efficient of variation = 100 × Co-efficient of dispersion
Co-efficient of variation = 100 × 0.2938
Co-efficient of variation = 29.38

Co-efficient of skewness
The co-efficient of skewness indicates the lack of symmetry in the given distribution, which is pure number independent of units of measurement. It is calculated by formula:
Co-efficient of skewness = (Mean – Mode / Standard deviation)
In the study area, computed rainfall parameters are
Mean = 1022.58 mm,
Mode = 1100 mm,
Standard deviation = 300.52 mm.

Co-efficient of Skewness = (Mean - Mode) / Standard deviation
Co-efficient of Skewness = (1022.58 – 1100) / 300.52
Co-efficient of Skewness = **- 0.2576**

The results of statistical method for the analysis of rainfall data for a period from 1985 to 2015 incorporates determinations of central tendencies (Mean (1022.58 mm.), Median (1012.5 mm.), Mode (1100 mm.),) and other different parameters, such as Standard Deviation (300.52 mm.), Coefficient of Dispersion (0.31), Coefficient of Variation (29.38), Coefficient of Skewness (0.2576) are indicating the positive trend of rainfall.

TIME SERIES ANALYSIS

The time series analysis decides a propensity to increment or diminishing, over a predefined period. Time series analysis gives an appealing representation on the grounds that the pattern is generally overwhelming; basically, no other development is distinguishing (Croxton *et.al.*, 1988). The time series investigation gives noteworthy data identifying with the portrayal of the pattern of series of perceptions (Gupta and Kapoor, 1986).

Time series examination gives vast data with respect to the pattern of arrangement of perception and it makes a difference:
1. To quantify the deviation from the pattern and Provides data on the idea of pattern. Consequently, this examination empowers us to figure the future conduct of pattern.

2. It encourages us to think about the adjustment in the estimation of various observable facts at various time set and so on.
3. It empowers us to think about the post conduct of the phenomena under thought i.e to decide the sort and nature of the variety in the information.
4. It assesses the genuine current execution of achievements with the normal ones and investigation the reasons for such variety, assuming any.

Methodology of time series analysis depicted by Gupta and Kapoor, (1986) has been followed in the present work. Technique suitable for Second degree Parabola has been connected for pattern examination of the behavior of yearly precipitation. Parabola condition can be communicated as.

$\Sigma y = na + b\Sigma t$…………………… ……………….. (1)

$\Sigma yt = a\Sigma t + b\Sigma t$…………………………………. (2)

Estimations of distinctive components in the above form have been controlled by considering (y) as factor (yearly rainfall) and (t) as steady (year). The assurances are made according to the accompanying system:

Time arrangement examination helps in influencing endeavor for the future behavior of rainfall trend.

$\Sigma y = na + b\Sigma t$……………………………………… (3)

$\Sigma yt = a\Sigma t + b\Sigma t$………………………………….. (4)

The estimations of various components in the above condition have been communicated by thinking about y as variable yearly rainfall and t as stable (year). The decided qualities are appeared in Table 3 and resolute according to the accompanying method:

$\Sigma y = 31336.8$, $\Sigma t = 0$, $\Sigma yt = 14416$, $\Sigma t^2 = 2480$

Place these values in the conditions (1) and (2) and we obtain these two conditions of (3) and (4).

Table: 3 Time series analysis of rainfall data of Ujjain region, Madhya Pradesh.

S. No.	**Year (X)**	***T***	***Annual Rainfall (Y)***	***T2***	***YT***
1	1985	-15.0	472.4	225	-7086
2	1986	-14.0	1253.6	198	-17550.4
3	1987	-13.0	862.7	169	-11215.1
4	1988	-12.0	976.4	144	11716.8
5	1989	-11.0	750.6	121	-8256.6
6	1990	-10.0	1211.6	100	-12116
7	1991	-9.0	918.8	81	-8269.2
8	1992	-8.0	631.4	64	-5051.2
9	1993	-7.0	1258.0	49	-8806
10	1994	-6.0	1250.3	36	-7501.8
11	1995	-5.0	1118.4	25	-5592
12	1996	-4.0	1266.1	16	-5064.4
13	1997	-3.0	1049.0	9	-3147
14	1998	-2.0	1013.0	4	-2026
15	1999	-1.0	960.8	1	-960.8
16	2000	0.0	970.0	0	0
17	2001	1.0	570.0	1	570
18	2002	2.0	810.6	4	1621.2
19	2003	3.0	1012.4	9	3037.2
20	2004	4.0	861.8	16	3117.2
21	2005	5.0	563.8	25	2819
22	2006	6.0	2019.0	36	12114
23	2007	7.0	1393.5	49	9754.5
24	2008	8.0	723.0	64	5784
25	2009	9.0	1097.0	81	9873

26	2010	10.0	1126.8	100	11268
27	2011	11.0	730.4	121	8034.4
28	2012	12.0	1069.5	144	12834
29	2013	13.0	1329	169	17277
30	2014	14.0	661.7	196	9263.8
31	2015	15.0	1405.2	225	21078
Total		∑x= 0	31336.8	2480	14416

Σy= na+bΣt…………………….......................... (3)
Σyt = aΣt + bΣt…………………….................... .(4)
31336.8 = 31(a) + b (0) ………………………....... ..(3)
14416 = a (0) + b (2480) ……………………….…... (4)
Resolve the condition 3 and 4. The estimations of a, and b obtained as 1010.86 and 5.81 correspondingly a condition of parabola is produced, which can be composed as:-
y= a+b (x-2000)… …...............................……….(5)
Utilize the condition – (5) and computed the future expected rainfall for a period of five years from 2016 to 2020 (Table 4).

Table 4: The future expected rainfall of Ujjain area.

S. No.	Years	Expected Rainfall
1	2016	1103.82
2	2017	1109.63
3	2018	1115.44
4	2019	1121.25
5	2020	1128.06

The future expected of rainfall reveal +_50 mm. less or more variation in the actual rainfall. The time series analysis of rainfall indicates a positive trend of rainfall for the future years.

Table 5. Comparative analysis of expected future rainfall and actual rainfall value.

S. No.	Years	Expected Rainfall	Actual value of rainfall	Difference
1	2016	1103.82	1413.5	+ 309.68
2	2017	1109.63	1209	+ 99.37

The comparative analysis of expected future rainfall and actual value of rainfall during the years of 2016 and 2017 indicate more than the forecasted value of rainfall pointing positive trend.

ENVIRONMENTAL IMPACTS

The most important climatologically feature of the South Asian region is the occurrence of monsoons, the southwest or summer monsoon being the principal source of water; and the northeast or winter monsoon meets the water needs of the southern parts of the Indian Peninsula and Sri Lanka. Monsoon rainfall affects millions of lives in India, which is greatly influenced by the shape of the continent, orography, and upper tropospheric conditions etc. that are best addressed by a regional approach (Guhathakurta and Rajeevan, 2008). Rainfall over India is subject to a high degree of variation leading to the occurrence of extreme monsoon rainfall deficit or excess over extensive areas of the country (Dash *et a*l., 2007).

The impact of climatic variations and changes on the seasonal hydrological cycle is a key issue for policy makers since India is strongly dependent on agriculture. Although the summer monsoon (June to September) is the major rain producing season over India, other seasons also have significant contribution in some specific region. Global water resources are highly sensitive to both climate change and climate variation.

Rainfall, the main input to the global hydrological cycle and an important indicator of water resources availability, has revealed significant change and variations over the years both globally and regionally. In this region, the rains are highly variable in time, space, amount and duration, and water is the most important limiting factor for biological and agricultural activities. (Zende *et, al*. 2012). The rainfall factor is a significant hydrometerlogical parameter, which causes both beneficial and harmful impacts on the environmental scenario, especially forest, society, surface and sub-surface water systems almost through the world. The excess of rainfall amount generates several natural problems such as river flooding, land slide, damages to population, property, agriculture and vegetation. The scarcity of rainfall results into water crises leading the drought condition, and recharge of ground water system. In recent years, the negative trends of rainfall and its further continuation is a warning to implement appropriate measures to increase the amount of rainfall by development of scheme of a forestation which will generate evapo-transpiration that will result in the increase of rainfall amount and intensity. It is also suggested that judicious use of water resource would also provide remedial measures to resolve the water crises because of rainfall factors.

CONCLUSION

The rainfall is an important hydro-meteorological parameter, which plays an important role in ground water recharge system. Rainfall data of the area have been analyzed by using both the mathematical and statistical methods. The available records of rainfall data for a period of 31 years (1985-2015). The rainfall data analysis of the Ujjain study area indicates a fairly good range of variations indicating the irregular positive and negative values as compared to the average annual rainfall. The results of statistical method for the analysis of rainfall data show positive trend in upcoming years. The rainfall data analysis indicates an environmental impact on the ground water system because when the annual rainfall is high, ground water recharge is high and when annual rainfall is low, ground water recharge is also low. Therefore, water should be used judiciously along with water conservation. The forecast of expected future rainfall for a period of next five years indicate a positive trend as compared to the annual average rainfall amount.

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