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Environmental implication of rainfall factor on recharge of ground water reservoir of Bagh area, Dhar district, Madhya Pradesh, India

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Abstract
The rainfall data analyses for a period of 31 years (1985 to 2015) have been conducted, which reveal the environmental impacts on recharge of ground water reservoir of the Bagh area, located in Dhar district of, Madhya Pradesh, India. The rainfall data have been analyzed by both the mathematical and statistical methods of data analysis. The mathematical analysis reveals a fairly good range of variation from 289.4 mm to 1230.mm with an average of 705.33 mm. The annual departures with respect to the average rainfall and cumulative departure indicate the positive and negative recharge trends of ground water reservoir. The statistical method of rainfall data provides the values of Mean = 1000.08 mm, Median = 1037.58 mm, Mode = 1222.22 mm, Standard Deviation = 328.59 mm, Co-efficient of Dispersion = 0.3254 mm, Co-efficient of Variation = 32.54 and Co-efficient of Skewness = - 0.6468. The statistical treatment of rainfall data provides precise values indicating the nature of recharge trend.
Time series analysis of rainfall data has been performed to forecast the trends of expected future rainfall. The computed high values than the average, infer the increasing trend of rainfall amount indicating favourable period for recharge to ground water system, whereas, low values than the average rainfall point the negative trend of ground water recharge that reflect shortage of water supply resulting into the water crisis. The rainfall is very important hydrometreological aspect, which controls the recharge of ground water system. The environmental impacts of rainfall on the ground water system have been discussed. Rainfall factor plays a key role by affecting the environment of forest, society, and optimum development of the agriculture and vegetation.

Keywords: Environmental implication, Rainfall, Recharge, Ground water system, Bagh, Dhar, Madhya Pradesh, India

1. Introduction

Rainfall is one of the most noteworthy meteorological 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. Precipitation is a widely used term for the rainfall, and it has been defined as liquid or solid products of the condensation of water vapour falling from clouds or deposited from air onto the ground. It includes rain, hail, snow, dew, rime, hoar frost and fog precipitation. The total amount of precipitation, which reaches the ground in a stated period is expressed in terms of the vertical depth of water (or water equivalent in the case of solid forms) to which it would cover a horizontal projection of the Earth's surface. Wisner (1970) [11] has defined rainfall (precipitation) as "the depositing of water from the atmosphere on to the surface. This deposit may be liquid or solid to give the various forms of precipitation".

The rainfall records reveal a wide variation range in the amount and frequencies from the place to place. Precipitation forms as water vapour is condensed, usually in rising air that expands and hence cools. The upward motion comes from air rising over mountains, warm air riding over cooler air (warm front), colder air pushing under warmer air (cold front), convection from local heating of the surface, and other weather and cloud systems. Precipitation is therefore also generally dependent on the presence of storms of one sort or another (Trenberth, 2011) [9]. In India, rainfall mostly occurs during the monsoon period (July to September). The amount and frequency of rainfall reflect the relevance in discerning the scope of surface runoff to the ground water recharge.

Status of Rainfall in India

India enjoys the diversity of seasons due to geographical locations. The country is characterized by four seasons: (a) Cold weather season (December – February), (b) Hot weather season (March – May), (c) Advancing South–West monsoon season (June–September), (d) Post or retreating monsoon season (October–November). The average maximum temperature is above 45 °C in the month of May at Delhi and Jodhpur. Such high temperature heats up the air of that region. Hot air rises, low pressure area is created under it. This low pressure is also known as monsoonal trough. It lies between Jaisalmer in the west and Balasore in Odisha in the East. On other hand, the temperature over Indian Ocean is relatively low, as water needs more time to get heated as compared to land. Hence, a relatively high pressure region is created over the sea.

The South-Western monsoon is the most considerable feature of the Indian climate. The season spreads over four months, but the actual period at a particular place depends on onset and withdrawal dates. It ranges from less than 75 days over West Rajasthan, to more than 120 days over the South-Western regions of the country contributing to about 75 % of the annual rainfall. The onset of South-Western monsoon usually starts over the Kerala coast, the southern end of the country by start of June, advances along the Konkan coast in early June and covers the whole country by middle of July. (Website of Indian Institute of Tropical Metrology)

India is an exceptional example of rainfall distribution with acute variations over a span in a year. In Peninsular region, the rainfall decreases from coast to interior parts. In North-East India, the rainfall increases with altitude. Both, one of the rainiest as well as driest places of the world are located in India. Pal (2009) classified the rainfall

States into the following categories descrined herein.

(1) Areas of heavy rainfall (more than 200cm): Maximum rainfall in India occurs in the western coast, sub Himalayan regions of north-east and Garo, Khasi and Jaintia hills of Meghalaya.
(2) Areas of Moderate rainfall (100-200cm): Areas receiving 100 to 200cm rainfall in India include some parts of the Western Ghats, West Bengal, Odisha and Bihar and many states.
(3) Areas of Low rainfall (60 to 100cm): This is the region of low rainfall, which includes parts of Uttar Pradesh, Rajasthan, and interior Deccan plateau.
(4) Areas of Inadequate rainfall (Less than 60cm): This is region of scanty rainfall. The western part of Rajasthan and Gujarat, Laddakh and south central part receives a rainfall of less than 20 cm.

Madhya Pradesh has a sub-tropical climate characterized by hot summer season and dryness except southwest monsoon season. Like most of north India it has a hot dry summer (April-June) followed by monsoon rains (July-September) and a cool and relatively dry winter (December- February). The maximum temperature during summer season ranges from 33 to 44ºC and 10 to 27º C during winter season. The average rainfall is about 1,370 mm which decreases from east to west. The south- eastern districts have the heaviest rainfall, some places receiving as much as 2,150 mm, while the western and north-western districts receive 1,000 mm or less.

The climate condition of Bagh study area in Madhya Pradesh belongs to semi-arid region. The maximum temperature goes up to 48.2^0 C during summer in the May and the minimum temperature falls down to 6.0^0 C during winter in the January. The winds in the area are light to moderate during summer and winter and during the end of the summer season and monsoon season. The predominant directions of wind have been observed from E, WWN, EEN and W. The rainfall ranges from July to September within a range of 630 to 700 mm. The monsoon provides over 90% of the total annual rainfall.

Rainfall Data Analysis of Bagh Area

The rainfall is measured with the help of instrument known as 'Rain Gauge' that the measures the amount of rain over a set period of time (Garg, 1979) [5]. The most commonly used type of rain gauge in India is the Symon's Rain Gauge. The annual rainfall data of last 31 years, (1985- 2015) have been collected from Ground Water Department, Dhar District, Madhya Pradesh. The rainfall data have been reproduced (Table 1). The rainfall data analyses have been carried out by using both mathematical and statistical methods.

Mathematical Method

The mathematical method is most commonly used for the 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 the average. The annual rainfall data for a period of 31 years (1985 to 2015) indicate that the maximum precipitation during the last two decades has been observed as 1187.0 mm and minimum rainfall of 289.4 mm during the year of 2006 and 1987 respectively was noted (Table 1, Figure 1). The annual average rainfall of the area has been calculated, as 705.33 mm.

Table 1: Annual Rainfall, Departure and cumulative departure from the annual average rainfall, in Dhar District, Madhya Pradesh.

S. No.	Year	Total Rainfall in mm	Departure from Average rainfall	Cumulative departure from average rainfall
1.	1985	635	-70.33	-70.33
2.	1986	794.5	89.17	18.84
3.	1987	289.4	-415.93	-397.09
4.	1988	412.7	-292.63	-689.72
5.	1989	694.4	-10.93	-700.65
6.	1990	720.5	15.17	-685.48
7.	1991	499	-206.33	-891.81
8.	1992	394	-311.33	-1203.14
9.	1993	776	70.67	-1133.14
10.	1994	940	234.67	-898.47
11.	1995	471.1	-234.23	-1132.7
12.	1996	781	75.67	-1057.03
13.	1997	709	3.67	-1053.36
14.	1998	928	222.67	-830.69
15.	1999	574	-131.33	-962.02
16.	2000	290	-415.33	-1377.35
17.	2001	627	-78.33	-1455.68
18.	2002	665	-40.33	-1496.01
19.	2003	649	-56.5	-1552.51
20.	2004	731.9	26.57	-1525.94
21.	2005	437	-268.33	-1794.27
22.	2006	1187	481.67	-1312.6
23.	2007	1155	449.67	-862.93
24.	2008	588	-117.33	-980.26
25.	2009	693	-12.33	-992.59
26.	2010	727	21.67	-970.92
27.	2011	673	-32.33	-1003.25
28.	2012	874	168.67	-834.58
29.	2013	1230	524.67	-309.91
30.	2014	765	59.67	250.24
31.	2015	955	249.67	0
Total Rainfall		21865.5		

Average Rainfall = 705.33 mm

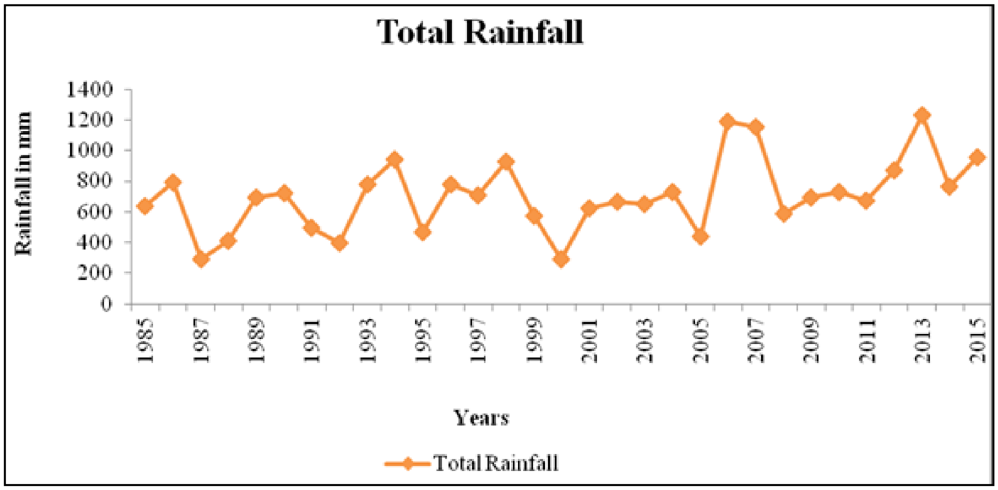

Fig 1: Total annual Rainfall for the periods of 1985-2015, Bagh area, Dhar district, M. P.

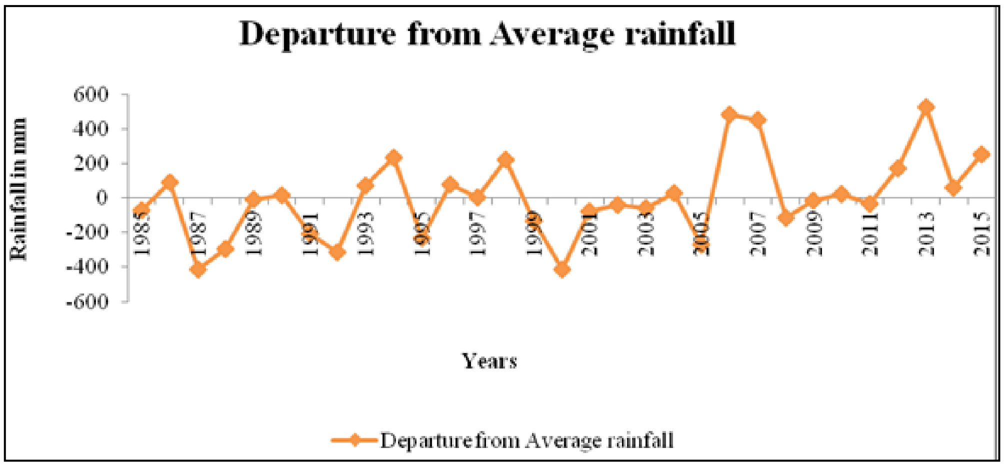

Fig 2: Departure from average rainfall (in mm.) for the periods of 1985-2015.

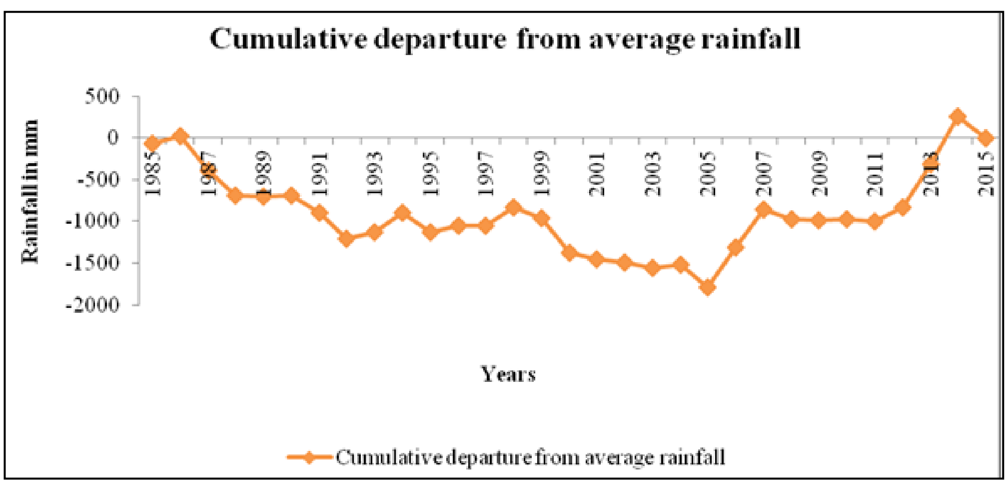

Fig 3: Cumulative departures from average rainfall (in mm.) for periods of 1985-2015.

The trend of departure from the average annual rainfall indicates favourable conditions during the years of 1986, 1987, 1990, 1991, 1993, 1994, 1999, 2001, 2003, 2004, 2006 to 2008. The rest of years indicates negative trend of ground water recharge (Figure 2), The Cumulative departure indicates a negative trend of rainfall to ground water system (Figure 3).

The rainfall data analysis has been carried out by mathematical and statistical techniques. The mathematical analyses indicate average annual value of Rainfall as 705.33 mm. and trend of recharge variation of ground water system.

Statistical Method

The term Geostatistics has been regarded as "a collection of numerical techniques that deal with the characterization of spatial attributes, employing primarily random models in a manner similar to the way in which time series analysis characterizes temporal data." (Olea, 1999). Deutsch, (2002) defined Geostatistics as "a study of phenomena that vary in space and/or time".

The statistical method for the analysis of rainfall data of study area for a period of 31 years (1985-2015), has been conducted and determines the central tendencies (Mean, Median, and Mode). Standard Deviation, Coefficient of Dispersion, Coefficient of Variation, Coefficient of Skewness by using Davis (1996, 2002) methods.

Table 2: Statistical Analysis of Rainfall Data of Bagh area Dhar District, Madhya Pradesh showing frequency distribution:

Class interval	Mid value	Frequency	U=(X-700)/200	FU	U^2	FU^2	Cumulative
200-400	300	3	- 2	- 6	4	12	3
400-600	500	6	-1	-6	1	6	9
600-800	700	15	0	0	0	0	24
800-1000	900	4	1	4	1	4	28
1000-1200	1100	2	2	4	4	8	30
1200-1400	1300	1	3	3	9	9	31
				-1	19	39	

Mean

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

$$\text{Mean} = A + \frac{(\Sigma fu)}{N} \times I$$

Where,

A = Assumed mean = 700
I = Class interval = 200
f = Frequency = fu = -1
N= Total frequency = 31

$$= \frac{700 + (-1)\,200}{31}$$

Mean = 693.55 mm.

Median

Median is defined as the variable which divides a set of observations and it is calculated by the use of given formula.

$$\text{Median} = l + \frac{(N/2 - f)}{F} \times 200$$

Where,

I = Lower limit of median class = 600
f = Frequency of Median class = 15
i = Magnitude of Median class = 200
c = Cumulative frequency of the class preceding the median class = 9

$$= 600 + \frac{(31/2 - 9)}{15} \times 200$$

$$= 600 + \frac{(15.5-9)}{15} \times 200$$

$$= 600 + 0.433 \times 200$$

Median = 686.66 mm.

Mode

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

$$\text{Mode} = L + \frac{f - f_1}{2f - f_1 - f_2} \times I$$

Where,

L = lower limit of the modal class = 600
f= frequency of the modal class = 15
f1 = frequency of the pre modal class = 6
f2 = frequency of the post modal class = 4
I = Interval class =200

$$\text{Mode} = L + \frac{f - f_1}{2f - f_1 - f_2} \times I$$

$$\text{Mode} = 600 + \frac{15 - 6}{2(15) - (-6 - 4)} \times 200$$

Mode = 690 mm.

Standard deviation

Standard deviation commonly represented by the Greek latter small sigma (σ) is the positive square root of the arithmetic mean of the squares of the deviation of the given values from their arithmetic mean.

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

Where,

σ . = Standard deviation
I = Class interval =200
N = Number of sample =31
Σfd2 = 39
Σfd = -1

Hence,

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

$$\sigma = 200\sqrt{\left\{\frac{1}{31}\times 39 - \left(\frac{1}{31}\times(-1\right)^2\right\}}$$

σ = **221.43 mm**

Co- efficient of dispersion

Whenever we want to compare the variability of the two series which are dispersion but we calculate the co-efficient of dispersion C. D) which are pure numbers independent of the units of measurement.

$$C.\ D. = \frac{\text{Standard Deviation}}{\text{Mean}}$$

$$= \frac{21.43}{693.54}$$

Co-efficient of Dispersion = 0.31

Co-efficient of Variation

Coefficient of variation has been defined as the percentage variation in the Mean and Standard Deviation is considered as the total variation in the mean.

The coefficient of variation (C.V.) is determined by the following expression-

$$\text{Co-efficient of variation (C.V.)} = \frac{\text{Standard Deviation}}{\text{Mean}}$$

$$= \frac{221.43 \text{ x } 100}{693.54}$$

co-efficient of variation = 31.92 mm.

Co-efficient of skewness

The co-efficient of skewness indicates the lack of symmetry in the given distribution. It is calculated by following expression-

$$\text{Co-efficient of Skewness} = \frac{\text{Mean - Mode}}{\text{Standard Deviation}}$$

$$= \frac{693.54\text{-}690}{221.43}$$

Co-efficient of Skewness = 0.015 mm.

The statistical analysis reveals that Mean (693.54 mm.), Median (686.66 mm.), Mode (690 mm.), Standard Deviation (221.43 mm.), Coefficient of Dispersion (0.31), Coefficient of Variation (31.92), Coefficient of Skewness (0.015). These parameters indicate the negative trend.

Time Series Analysis

The time series analysis generates valuable information about trend of a series of observations. It helps in measurements of the deviation from the trend and enables information pertaining to the nature of trend. This analysis is regarded as a tool to forecast the future behaviour of trend. It helps us to compare the changes in values of different phenomena at diverse times or place, and also enables us to study the post behaviour of the phenomena under consideration i.e., to determine the type and nature of the variation in data. The time series analysis provides

The statistical analysis reveals that Mean (693.54 mm.), Median (686.66 mm.), Mode (690 mm.), Standard Deviation (221.43 mm.), Coefficient of Dispersion (0.31), Coefficient of Variation (31.92), Coefficient of Skewness (0.015). These parameters indicate the negative trend.

The significant information relating to the characterization of the trend of series of observations (Gupta and Kapoor, 1977). Time series analysis helps to compare the changes in values of different phenomena under consideration i.e. to determine the type and nature of the variation in data. The main objective in time series analysis is to understand, interpret and evaluate changes in economic phenomena in the hope of more correctly anticipating the course of future event.

Time series analysis is one of the most essential methods for short term forecasting. This analysis looks for the dependence between values in a time series and a set of values recorded at equal time intervals with a view to accurately identify the underlying pattern of the data. The earlier trends can be projected in to future trends, to predict the changes, which are likely to occur in economic and hydrometereological cycle.

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

The value of 'a' and 'b' must be determined from the 31 years observed data. This is done by simultaneous solving of two common equations:

$$\Sigma y = n\,a + b\,\Sigma t \quad \text{.... (1)}$$

$$\Sigma y\,t = a\,\Sigma t + b\,\Sigma t^2 \quad \text{.... (2)}$$

The values of the different elements in the above equation have been determined by considering Y as variable (annual rainfall) and T as constant (year). The determined values are displayed (Table 3). The determinations are completed as per the following procedure:

$\Sigma Y = 21865.5$

$\Sigma T = 0$,

$\Sigma Y T = 28393.1$

$\Sigma t^2 = 2480$

Plotting these values in normal equation (1) and (2), the two new equations (3) and (4) are developed.

$$21865.5 = 31(a) + b\,(0) \quad \text{.... (3)}$$

$$28393.1 = a\,(0) + b\,(2480) \quad \text{.... (4)}$$

Solving the equations (3) and (4), the values of '*a*' and 'b' are obtained as 705.33 and 11.44 respectively. The future forecast of rainfall amount for a period of five years (Table4) from 2016 to 2020 has been made. The time series analysis reveals ± 50 mm variations in the expected amount. Future forecast is calculated by given equation:

$$Y = a + b\,(X - 2000)$$

Table 3: Time Series Analysis of Rainfall Data of the Study Area.

No.	Year	T	Rainfall Y	T^2	YT
1	1985	-15	635	225	-9525
2	1986	-14	794.5	196	-11123
3	1987	-13	289.4	169	-3762.2
4	1988	-12	412.7	144	-4952.4
5	1989	-11	694.4	121	-7638.4
6	1990	-10	720.5	100	-7205
7	1991	-9	499	81	-4491
8	1992	-8	394	64	-3152
9	1993	-7	776	49	-5432
10	1994	-6	940	36	-5640
11	1995	-5	471.1	25	-2355.5
12	1996	-4	781	16	-3124
13	1997	-3	709	9	-2127
14	1998	-2	928	4	-1856
15	1999	-1	574	1	-574
16	2000	0	290	0	0
17	2001	1	627	1	627
18	2002	2	665	4	1330
19	2003	3	649	9	1947
20	2004	4	731.9	16	2927.6
21	2005	5	437	25	2185
22	2006	6	1187	36	7122
23	2007	7	1155	49	8085
24	2008	8	588	64	4704
25	2009	9	693	81	6237
26	2010	10	727	100	7270
27	2011	11	673	121	7403
28	2012	12	874	144	10488
29	2013	13	1230	169	15990
30	2014	14	765	196	10710
31	2015	15	955	225	14325
	Total	0	21865.5	2480	28393.1

The future forecast of rainfall amount for period of five years from 2016 to 2020 has been given below:

$$Y = a + b\,(X - 2000)$$
$$Y = 705.33 + 11.44(X-2000)$$

Table 5: Forecast of Expected Future Rainfall

S. No.	Years	Expected Rainfall
1	2016	888.37
2	2017	899.81
3	2018	911.25
4	2019	922.69
5	2020	934.13

Environmental impactions of Rainfall

The environmental implications of rainfall factor on the recharge of ground water system of Bagh area of Dhar district, Madhya Pradesh, India, have been discussed herein. The rainfall data analysis of Bagh area reveals a fairly good range of variation of rainfall, which reflects implications on the status of recharge of the ground water system. It is well known fact that the rain water is the major source to the recharge of ground water reservoirs and affects the environmental scenario. Todd, (1980) remarked that the ground water levels may exhibit seasonal variation due to rainfall. Drought extending over a period of several years, contribute to declining water levels. The depletion of ground water levels may be assigned to seasonal variation in the static groundwater levels, which are governed by the infiltration of rainwater.

Rainfall plays a very considerable role in the environmental scenario. The excess rainfall results into flooding of a river and causes damage to vegetation and crops. The scarcity of rainfall results into shortage of water supply and ultimately in drought situation. The average value of rainfall has been determined as 705.33 mm. The rainfall variation plays a major role in the ground water recharge phenomena. The rainfall data analysis of Bagh area reveals a fairly good series of variation pointing out the positive and negative trends that influence the recharge of the ground water system. It is recommended that the scheme of rainfall augmentation is required for implementation in the Bagh area with a view to obtain sustained water supply.

Conclusion

Rainfall is a very important hydro meteorological factor, which plays vital role in environmental entity as a major source for the recharge of ground water system. The rainfall data records of 31 years 1985-2915) in respect of the Bagh study area have been analyzed by mathematical as well as statistical techniques. The analyzed data disclose the trend of vaiations that may be assigned to the variation in seasonal temperatures. The rainfall factor has played a imperative role in the recharge phenomena of ground water system.

The time series analysis of the rainfall data has been conducted for the approximation of future rainfall trend for the next five years, which exhibits positive trend of the recharge. The environmental impacts of rainfall factor in the recharge of ground water system have been discussed. It is visualized that augmentation of rain water would enhance the recharge phenomena of ground water system. The execution of an appropriate measures may provide remedy in managing the rapidly growing scenario of ground water level depletion resulting in the scarcity of water and even a drought condition in the Bagh area.

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