P: ISSN No. 0976-8602 RNI No.UPENG/2012/42622 VOL.-7, ISSUE-4, October-2018

E: ISSN No. 2349-9443 Asian Resonance

Analysis of Thandla Rainfall Data, Forecasting and Environmental Implications on Ground Water System Recharge, Jhabua District, Madhya Pradesh, India

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Abstract

Rainfall is a one of the most indispensable hydrometereological factor, which governs the recharge phenomena of ground water system. The paper deals with the results of rainfall data analysis for a period of 25 years (1992 to 2016) and environmental implications on ground water system recharge of Thandla area, Jhabua district.

Mathematical analysis of Thandla rainfall data indicates a variation range from 423.00 to 2086.20 mm. The minimum annual rainfall (423.00 mm) has been recorded during 2000, and maximum rainfall (2086.20 mm) has been observed during 1997, and computed annual average rainfall value as 964.324 mm. Departure from the average annual rainfall and Cumulative average have been determined. Statistical analysis of rainfall data indicates values of mean (976 mm.), median (960 mm.), mode (1140 mm.), standard deviation (412 mm.), co-efficient of dispersion (0.422), co-efficient of variation (42.213), and co-efficient of skewness (-0.398). Computed values of statistical parameters indicate a negative trend of rainfall. Forecast of expected rainfall trend for 9 years has been visualized.

Environmental impacts of rainfall trends on ground water system recharge have been discussed. It is recommended that the augmentation of rainfall is the priority need to resolve the prevailing water crisis by adopting construction of artificial recharge structures and launching of the aforestation programme in Thandla study area.

Keywords: Rainfall Data Analysis, Ground Water Recharge, Environmental Impacts, Thandla Area, Jhabua District, Madhya Pradesh, India.

Introduction

Rainfall is a generally recognized term for precipitation and it is one of the noteworthy hydrometeorological parameters, which plays a significant role in the recharge of ground water reservoir. Usually, liquid form of precipitation is generally identified as rainwater or rainfall that acts as a key source for the recharge of ground water system. According to Wiesner (1970), rainfall is a common term used for precipitation, which involves depositing of water from the atmosphere on to the surface. This deposit may be either liquid or solid to provide the various forms of precipitation. In India, rainfall mostly occurs during the monsoon period. Generally, rainfall amount is measured by using rain gauge. The recorded values of rainfall are expressed in inch, mm or cm. The rainfall records indicate a fairly good range of variation in the amounts and frequencies from place to place. The duration and frequency of rainfall help in determination of the scope of surface runoff for ground water recharge and estimation of water balance of a basin. Katara and Dev (2016) published results of rainfall data (1987 to 2011) analysis and environmental impacts on ground water reservoir. This paper deals with data analysis of rainfall for a period of (1992 to 2016), forecasting and environmental implications. Nigwal and Dev (2016) published a paper on rainfall data analysis of Meghnagar area which is adjoining to present study area of Jhabua district.

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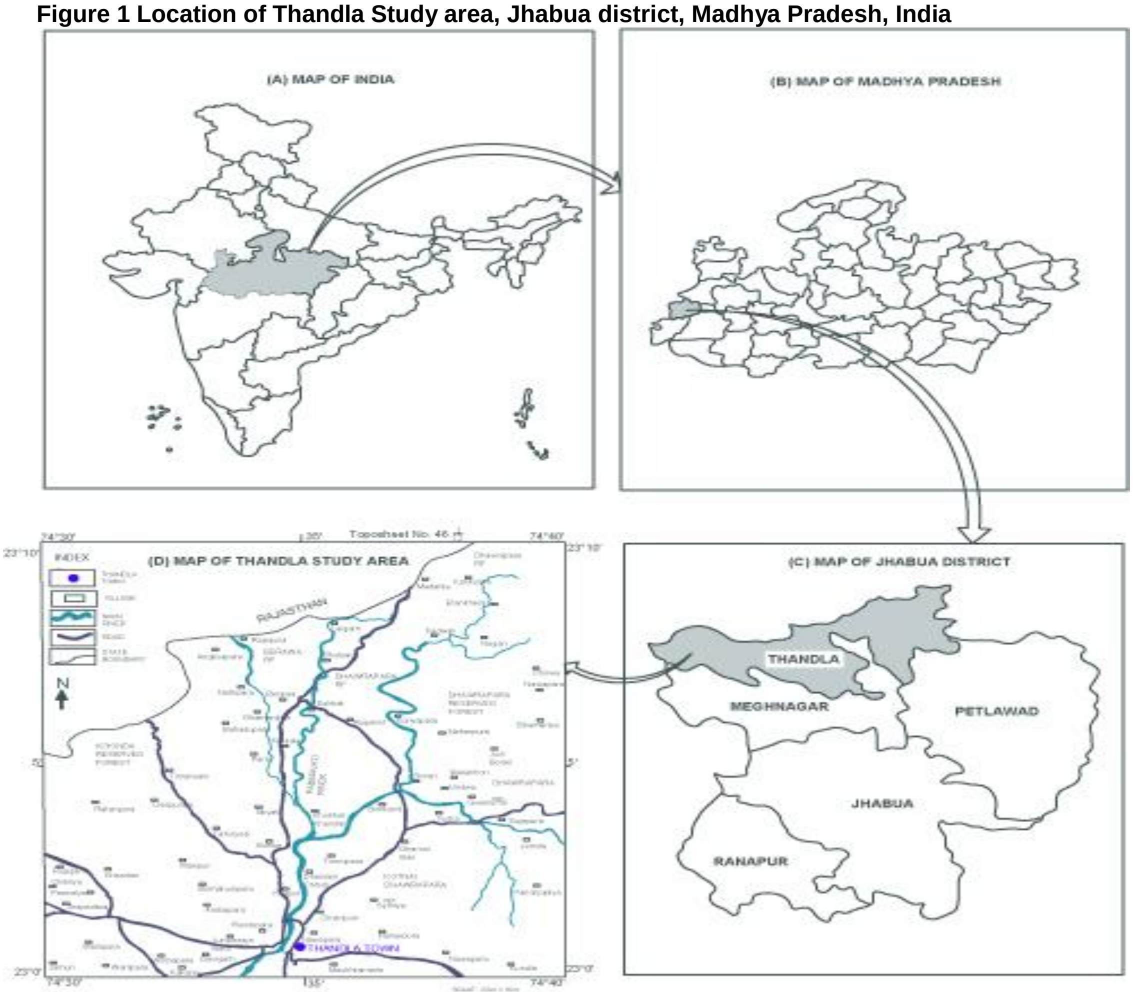
Aim of the Study

The most important aim of present paper is to record results of rainfall data subjected to mathematical and statistical, forecasting of expected rainfall trend and the environmental implications on ground water system recharge in Thandla area of Jhabua district, Madhya Pradesh, India.

Features of Study Area

The present study area is located in N - E of Thandla town in Jhabua district, Madhya Pradesh, within Latitude 23 ^{0} 0' to 23 ^{0} 10 ' N and Longitude 74 ^{0} 30 ' to 74 ^{0} 40 ' E, Survey of India Toposheet No.46 I/12, (Figure 1) in Thandla, Jhabua district. The area is 366.58 sq. km. It is located at a distance of 5 km. from South of the Thandla Road railway station. The temperature varies from 6 ^{0} C to 46 ^{0} C. Normally the area is mainly dry. The inhabitants of Thandla study area enjoy the monsoon season and feel happy. The annual rainfall varies from 423.00 to 2086.20 mm, with an average rainfall of 964.324 mm, and relative humidity is 34.4 to 50 %. The study area is dominated by the occurrence of quartzite, phyllite, basaltic lava flows having joints and fractures with black cotton, lateritic, and alluviul soils. Padmavati River mainly drains the study area, which is characterized by the dendritic drainage pattern

Figure 1 Location of Thandla Study area, Jhabua district, Madhya Pradesh, India



Analysis of Rainfall Data

Rainfall records of Thandla area for a period of 25 years (1992 to 2016) have been collected from the Collectorate Office, Jhabua district. Rainfall data have been subjected to both the mathematical and statistical techniques Analytical procedures have been described. Environmental impacts of rainfall factor on the ground water system recharge have been visualized and discussed herein.

Mathematical Analysis

Mathematical analysis is commonly employed for the rainfall data analysis (Falahah, *et. al.* 2010). The procedure involves computation of annual rainfall data for determining the average for the period of specific month or years as arithmetic mean. The determined values are expressed in mm, and displayed (Table 1 and 2). The variation in rainfall is indicated by a arithmetic stable mean. The calculations of departure from average of rainfall, the monthly, annual rainfall and cumulative average of rainfall of the study area have been computed and illustrated (Figure 2, 3, 4).

The rainfall data of Thandla area exhibit a fairly good variation range from 423.00 mm to 2086.20 mm. Minimum rainfalls of 423.0 mm has been recorded during year 2000, and the maximum rainfall of 2086.20 mm has been observed during year of 1997. The mathematical analysis indicates annual average rainfall value of 964.32 mm.

Table 1
Rainfall data for a period of 1992-2016 in respect of Thandla area, Jhabua district, Madhya Pradesh

S. No.	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual Total
1.	1992	-	-	-	-	11.0	40.7	83.3	279.6	149.0	82.6	28.4	-	674.6
2.	1993	-	-	8.0	-	26.2	48.2	731.6	232.6	95.4	15.0	-	-	1157.0
3.	1994	18.4	-	-	9.4	-	314.8	483.0	500.8	357.0	-	23.0	-	1706.4
4.	1995	36.6	-	2.8	-	-	30.0	377.8	152.8	96.6	12.4	-	-	709.0
5.	1996	-	-	-	-	-	47.2	503.4	441.2	244.6	49.4	-	-	1285.8
6.	1997	-	-	-	-	-	94.8	1456.0	306.4	116.8	22.0	-	90.2	2086.2
7.	1998	-	-	-	-	-	132.6	288.6	144.6	304.4	109.8	4.8	-	984.8
8.	1999	-	5.0	-	-	-	82.0	129.8	23.8	122.8	82.3	-	-	445.7
9.	2000	-	-	-	-	-	110.0	141.0	166.0	6.0	-	-	-	423.0
10.	2001	-	-	-	-	-	193.6	191.4	201.0	-	55.2	-	-	641.2
11.	2002	-	-	-	-	-	206.0	69.0	155.5	156.4	-	-	-	586.9
12.	2003	-	-	-	-	-	214.0	447.0	247.7	185.3	-	-	-	1094.0
13.	2004	-	-	-	-	-	163.0	247.0	540.8	94.0	25.0	-	-	1069.8
14.	2005	-	-	-	-	-	59.0	422.0	64.0	217.0	-	-	-	762.0
15.	2006	-	-	-	-	-	192.0	374.0	710.2	269.8	-	-	-	1546.0
16.	2007	-	-	-	-	-	76.6	552.4	508.2	163.8	-	-	-	1301.0
17.	2008	-	-	-	-	-	65.0	93.0	199.4	104.4	4.0	-	4.6	470.4
18.	2009	-	-	-	-	-	30.2	359.3	102.8	-	32.8	6.0	-	531.1
19.	2010	-	-	-	-	-	77.2	183.4	278.8	116.8	5.2	107.2	-	768.6
20.	2011	-	-	-	-	-	29.8	410.1	452.1	247.6	-	-	-	1139.6
21.	2012	-	-	-	-	-	3.0	320.9	401.8	388.0	-	-	-	1113.7
22.	2013	-	-	-	-	-	208.2	532.2	284.4	146.2	8.0	-	-	1179.0
23.	2014	-	-	20.0	19.1	-	-	314.0	218.2	142.0	22.4	-	-	735.7
24.	2015	-	-	-	-	-	167.1	452.5	49.0	20.4	18.4	-	-	707.4
25.	2016	-	-	-	-	-	41.3	213.8	512.2	157.7	64.2	-	-	989.2
Monthly Total		**55.0**	**5.0**	**30.80**	**28.50**	**37.20**	**2626.30**	**9376.50**	**7173.90**	**3902.0**	**608.70**	**169.40**	**94.80**	**24108.1**
Monthly Average		**2.2**	**0.20**	**1.23**	**1.14**	**1.48**	**105.05**	**375.06**	**286.95**	**156.08**	**24.34**	**6.77**	**3.79**	**964.32**
Cumulative Average		**2.20**	**2.40**	**3.63**	**4.77**	**6.26**	**111.31**	**486.37**	**773.32**	**929.40**	**953.75**	**960.53**	**964.32**	**-**
Annual Average Rainfall (1992-2016) = 964.32														

Figure 2

Monthly average rainfall data of Thandla area, Jhabua district, Madhya Pradesh

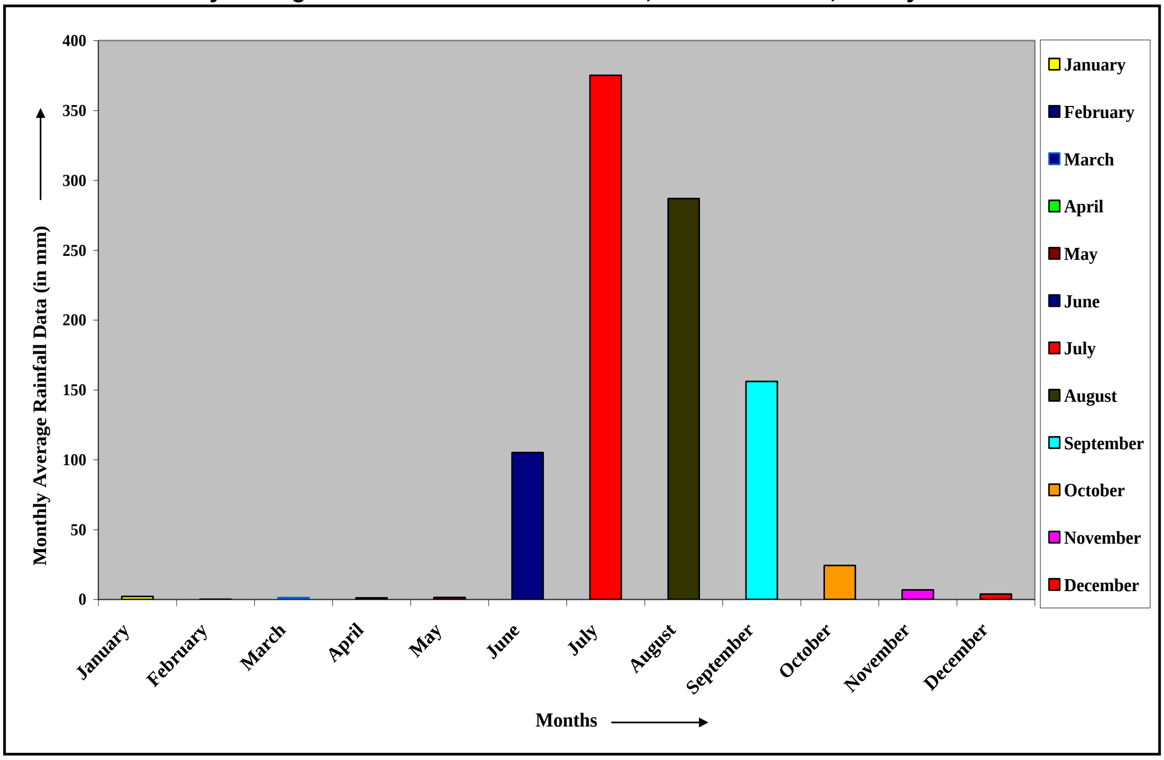


Figure 3

Total annual rainfall data (1992-2016) of Thandla study area, Jhabua district, Madhya Pradesh

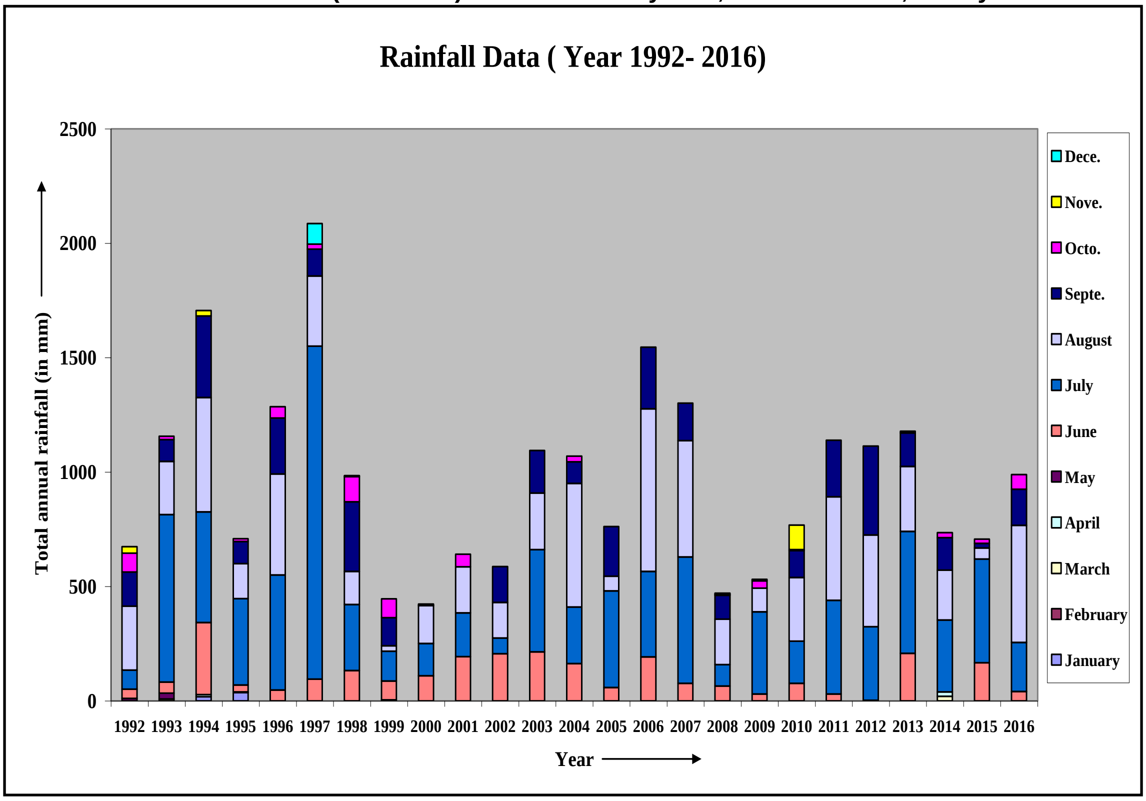


Figure 4

Cumulative average rainfall data of Thandla area, Jhabua district, Madhya Pradesh.

Departure from the Average

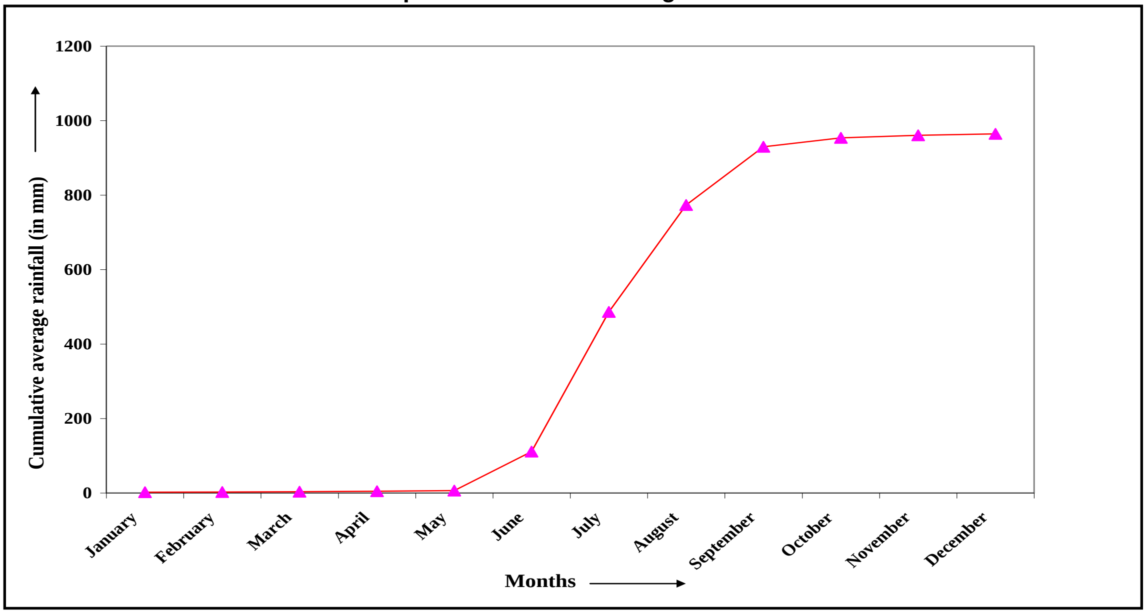


Table 2

Annual rainfall, its departure and cumulative departure from average rainfall in Thandla area, Jhabua district, Madhya Pradesh

S. No.	Year	Total annual rainfall (mm.)	Departure from average rainfall (mm.)	Cumulative departure from average rainfall (mm.)
1.	1992	674.6	- 289.724	- 289.724
2.	1993	1157.0	192.676	- 97.048
3.	1994	1706.4	742.076	645.028
4.	1995	709.0	- 255.324	389.704
5.	1996	1285.8	321.476	711.18
6.	1997	2086.2	1121.876	1833.056
7.	1998	984.8	20.476	1853.532
8.	1999	445.7	- 518.624	1334.908
9.	2000	423.0	- 541.324	793.584
10.	2001	641.2	- 323.124	470.46
11.	2002	586.9	- 377.424	93.036
12.	2003	1094.0	129.676	222.712
13.	2004	1069.8	105.476	328.188
14.	2005	762.0	- 202.324	125.864
15.	2006	1546.0	581.676	707.54
16.	2007	1301.0	336.676	1044.216
17.	2008	470.4	- 493.924	550.292
18.	2009	531.1	- 433.224	117.068
19.	2010	768.6	- 195.724	- 78.656
20.	2011	1139.6	175.276	96.62
21.	2012	1113.7	149.376	245.996
22.	2013	1179.0	214.676	460.672
23.	2014	735.7	- 228.624	232.048
24.	2015	707.4	- 256.924	- 24.876
25.	2016	989.2	24.876	0

Figure 5

Departure from average annual rainfall in Thandla area, Jhabua district

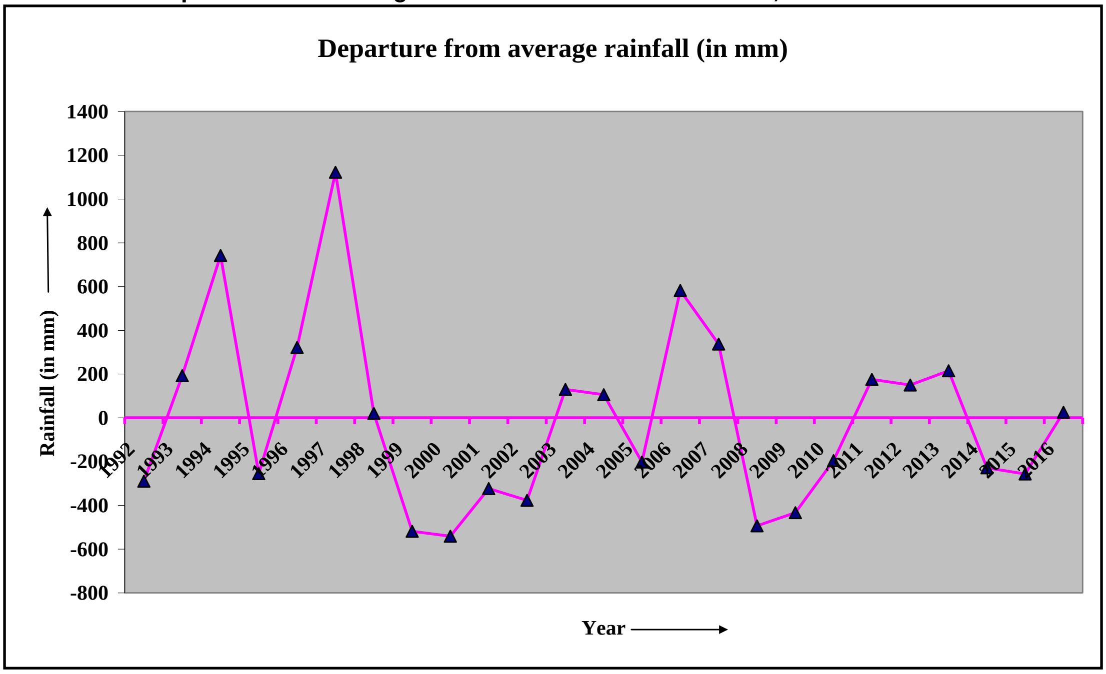
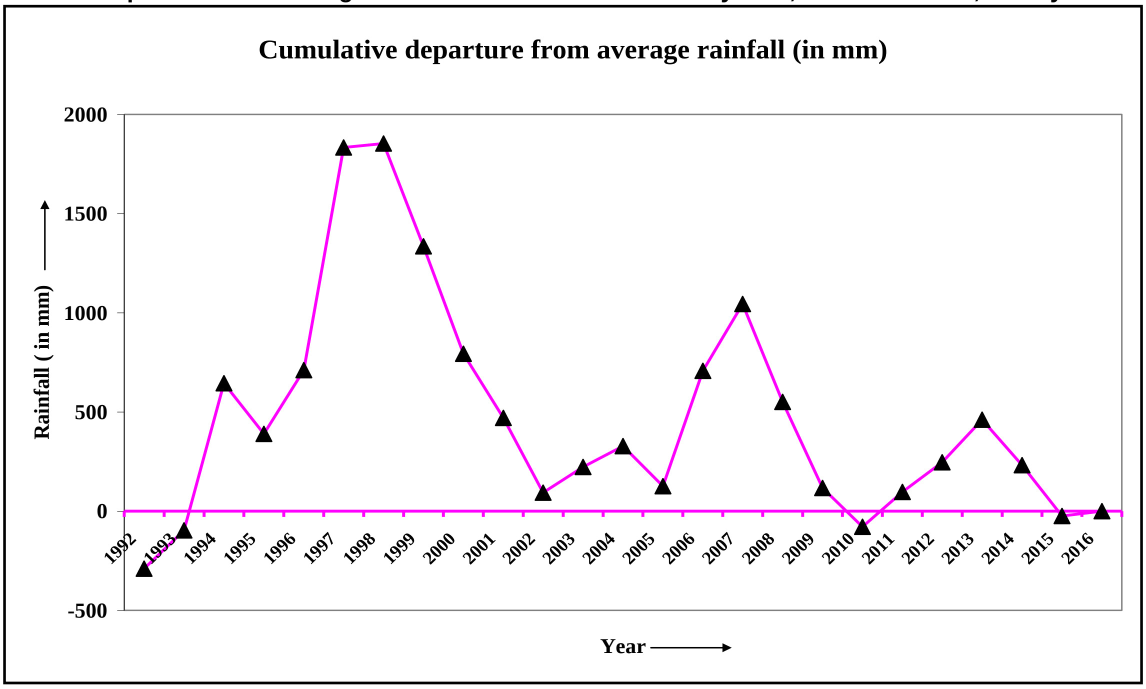


Figure 6

Cumulative departure from average annual rainfall in Thandla study area, Jhabua district, Madhya Pradesh.



The departure from the annual average value and cumulative departure have been displayed (Table 2, Figure 5, 6). The rainfall during the years of 1993, 1994, 1996, 1997, 1998, 2003, 2004, 2006, 2007, 2011, 2012, 2013, 2016 have been more than the average rainfall and indicate favorable conditions for the ground water recharge, while the years of 1992, 1995, 1999, 2000, 2001, 2002, 2005, 2008, 2009, 2010, 2014, and 2015 point out the rainfall values below the average rainfall indicating rather less contribution of rainwater to the ground water reservoir.

Statistical Analysis

Thandla rainfall data have been subjected to the statistical analysis, which deals with the computation of different parameters, such as mean, median, mode, standard deviation, co-efficient of dispersion, co-efficient of variation and co-efficient of skewness (Table 3). The statistical analysis of rainfall data analysis has been carried out by adopting standard methods of data analysis, namely Croxton, *et. al.* (1988); Davis (1975, 1986, 2002); Gupta and Kapoor (2003); Sahai, *et. al.*(2003); Goswami *et. al.*

(2006); and Falahah *et. al.* (2010). The procedure of determination of statistical parameters of rainfall data are described in the following text.

Mean

Mean for a set of observation, it is their sum divided by the number of observation. It is computed by the equation: Mean $(\overline{X}) = A + \frac{\sum fu}{N} \text{ x } I$

Where, A = Assumed mean = 1200, I = Class interval = 200, $\sum fu$ = - 28, N = Total frequency = 25

$$\overline{X} = 1200 + \frac{(-28)}{25} \text{ x } 200$$

$$\overline{X} = 1200 + \frac{(-5600)}{25}$$

$$\overline{X} = 1200 + (-224)$$

$$\overline{X} = 1200 - 224$$

$$\overline{X} = 976\, mm$$

Mean $(\overline{X}) = 976$ *mm*

The mean rainfall of the study area is 976 mm.

Table 3

Computation of Statistical Parameters of Rainfall Data of Thandla Area, Jhabua District, Madhya Pradesh

S. No.	Class Interval	Mid Value (x)	Frequency (f)	fx	u = (x-a) / I	fu	u^2	fu^2	C. F. (Cumulative Frequency)
1.	300-500	400	3	1200	-4	-12	16	48	3
2.	500-700	600	4	2400	-3	-12	9	36	7
3.	700-900	800	5	4000	-2	-10	4	20	12
4.	900-1100	1000	4	4000	-1	-4	1	4	16
5.	1100-1300	1200	5	6000	0	0	0	0	21
6.	1300-1500	1400	1	1400	1	1	1	1	22
7.	1500-1700	1600	1	1600	2	2	4	4	23
8.	1700-1900	1800	1	1800	3	3	9	9	24
9.	1900-2100	2000	1	2000	4	4	16	16	25
Total		**10800**	**$\sum$f = 25 = N**	**Σfx = 24400**	**Σu = 0**	**Σfu = -28**	**Σ u^2 = 60**	**$\sum fu^2$ = 138**	-

Median

Median is the variable for a set of observation, which is divided into two equal parts. It is determined by the formula: Median (M) = $L + \frac{½N - F}{f} \text{x} I$

Where, L = Lower limit of median class = 1100, I = Class interval = 200,
N = Number of total frequency = 25, F = Cumulative frequency of class preceding the median class = 16, f = Frequency of median class = 5

$$\text{M} = 1100 + \frac{½\ 25 - 16}{5} \text{ x } 200$$

$$\text{M} = 1100 + \frac{12.5 - 16}{5} \text{ x } 200$$

$$\text{M} = 1100 + \frac{-3.5}{5} \text{ x } 200$$

$$\text{M} = 1100 - 140$$

$$\text{M} = 960 \text{ mm}$$

Median (M) = 960 mm

Mode

The mode is a value that occurs as frequency in a given set of observation. It is calculated by using the following formula: Mode (M_0) = $l_1 + \frac{f_1 - f_0}{2f_1 - f_0 - f_2} \text{ x } I$

Where, l_1 = Lower limit of model class = 1100, f_1 = Frequency of modal class = 5,
f_0 = Frequency of class preceding the modal class = 4, f_2 = Frequency of class succeeding the model class = 1, I = Class interval = 200

$$\text{M}_0 = 1100 + \frac{5 - 4}{2 \text{x}\ 5 - 4 - 1} \text{ x } 200$$

$$\text{M}_0 = 1100 + \frac{1}{10 - 5} \text{ x } 200$$

$$\text{M}_0 = 1100 + \frac{1}{5} \text{ x } 200$$

$$\text{M}_0 = 1100 + 40$$

$$\text{M}_0 = 1140 \text{ mm}$$

Mode (M_0) 1140 mm.

Standard Deviation

Standard Deviation is a positive square root of the arithmetic mean of the squares deviation of a given value for their arithmetic mean. Standard deviation (σ) is calculated by the formula: Standard Deviation (σ) = $I\sqrt{\frac{(\sum fu^2)}{\sum f} - \left(\frac{\sum fu}{\sum f}\right)^2}$

Where, σ = Standard Deviation, I = Class interval = 200, $\sum f$ = Number of total frequency = 25, $\sum fu^2$ = 138, $\sum fu$ = -28

$$\sigma = 200\sqrt{\frac{138}{25} - \left(\frac{-28}{25}\right)^2}$$

$$\sigma = 200\sqrt{5.52 - \frac{784}{625}}$$

$$\sigma = 200\sqrt{5.52 - 1.25}$$

$$\sigma = 200\sqrt{4.27}$$

$$\sigma = 200 \text{ x } 2.06$$

$$\sigma = 412$$

Standard Deviation (σ) = 412 mm.

The calculated value of standard deviation (σ) reveals that deviation of rainfall is of 412 mm over a period of 25 years.

Co-efficient of Dispersion

The parameter is the measure of scatteredness and is determined by the formula given herein:

Co-efficient of Dispersion (CD) = $\sigma/\overline{X}$

Where, $\sigma =$ Standard Deviation = 412, $\overline{X}$ = Mean = 976

CD = 0.422

Co-efficient of Dispersion (CD) = 0.422

Co-efficient of Variation

It is the percentage variation in the mean. Standard deviation being considered as the total variation in the mean. Co-efficient of variation (CV) is calculated by the expression:

Co-efficient of Variation (CV) = $\frac{\sigma}{\overline{X}} \text{ x } 100$

Where, σ = Standard deviation = 412, $\overline{X}$ = Mean = 976

$$CV = \frac{412}{976} \text{x} 100$$

$$CV = \frac{41200}{976}$$

CV = 42.213

Co-efficient of variation (CV) = 42.213

The extent to which the amount in rainfall varies from year to year is given by co-efficient of variation. The calculated value of co-efficient of variability represents that the amount of rainfall varies up to 42.213.

Co-efficient of Skewness

It is lack of symmetry in the given distribution. It is denoted by the symbol S_k and computed by using the formula: Co-efficient of Skewness (S_k) = $\frac{\overline{X} - M_0}{\sigma}$

Where, $\overline{X}$ = Mean = 976, M_0 = Mode = 1140, σ = Standard Deviation = 412

$$S_k = \frac{976 - 1140}{412}$$

$$S_k = \frac{-164}{412}$$

$$S_k = -0.398$$

Co-efficient skewness (S_k) = -0.398

The co-efficient of skewness has been noted as -0.398 which indicates that there is lack of symmetry in the rainfall amount.

The statistical analysis of Thandla rainfall data indicate value of mean = 976 mm, median = 960 mm, mode = 1140 mm, standard deviation = 412 mm, co-efficient of dispersion = 0.422, co-efficient of variation = 42.213, and co-efficient of skewness = -0.398 and These computed values of statistical parameters indicate a negative trend of rainfall.

Time Series Analysis

Time series analysis provides valuable information in respect of trend for a series of observations. The analysis helps in forecasting of the future pattern of rainfall trend. The procedure adopted by Croxton *et. al.* (1988), Davis (2002), Gupta and Kapoor (2003) have been used for the analysis of rainfall data of Thandla area, Jhabua district, Madhya Pradesh. The behavior of rainfall trend has been observed on the basis of least square fit of straight line. The values of a and b can be determined from the observed data. Simultaneous solving of the following normal equations-

$\sum Y = Na + b\sum X$..................... (i)

$\sum XY = a\sum X + b\sum X^2$.............. (ii)

The values of the different elements in the above equation have been determined by considering Y as variable (annual rainfall), N as number of year and X as constant (year).

The determination are made as per the following procedure -

$\sum Y = 24108.1$, $\sum X = 0$, $\sum XY = -11765.4$, $\sum X^2 = 1300$, N = 25

Substituting these values in normal equation (i) and (ii), two equations in terms of (iii) and (iv) are developed -

24108.1 = (25) a + b (0)................. (iii)

-11765.4 = a (0) + b (1300).............. (iv)

Solving equation (iii) and (iv), the value of a and b are obtained as 964.32 and - 9.05 respectively. Trend value is determined by the following equation-

Yc = a + b ....(v)

The approximation of future forecast of rainfall amount for a period of Nine year (2017 - 2025) has been made and these values may indicate - 9.05 mm, variation in the expected amount. The computed values of future rainfall pattern are as follows-

2017 = 846.67 mm, 2018 = 837.62 mm, 2019 = 828.57 mm, 2020 = 819.52 mm, 2021 = 810.47 mm, 2022 = 801.42 mm, 2023 = 792.37 mm, 2024 = 783.32 mm, and 2025 = 774.27 mm (Table 4, 5 and Figure 7).

P: ISSN No. 0976-8602 RNI No.UPENG/2012/42622 VOL.-7, ISSUE-4, October-2018

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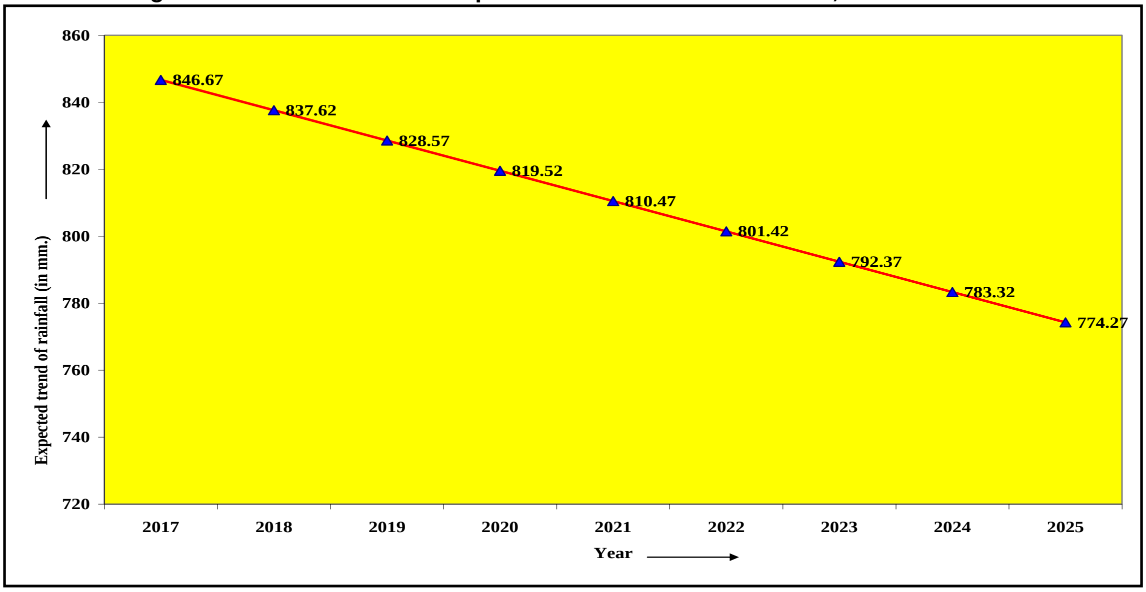
Table 4 Time Series Analysis of Rainfall Data of Study Area, Jhabua District, M. P.

S. No.	Year	X	Y (Rainfall)	X^2	XY	X^3	Trend value Yc
1.	1992	- 12	674.6	144	- 8095.2	- 1728	1072.92
2.	1993	- 11	1157.0	121	- 12727.0	- 1331	1063.87
3.	1994	- 10	1706.4	100	- 17064.0	- 1000	1054.82
4.	1995	- 9	709.0	81	- 6381.0	- 729	1045.77
5.	1996	- 8	1285.8	64	- 10286.4	- 812	1036.72
6.	1997	- 7	2086.2	49	- 14603.4	- 343	1027.67
7.	1998	- 6	984.8	36	- 5908.8	- 216	1018.62
8.	1999	- 5	445.7	25	- 2228.5	- 125	1009.57
9.	2000	- 4	423.0	16	- 1692.0	- 64	1000.52
10.	2001	- 3	641.2	9	- 1923.6	- 27	991.47
11.	2002	- 2	586.9	4	- 1173.8	- 8	982.42
12.	2003	- 1	1094.0	1	-1094.0	- 1	973.37
13.	2004	0	1069.8	0	0	0	964.32
14.	2005	1	762.0	1	762.0	1	955.27
15.	2006	2	1546.0	4	3092.0	8	946.22
16.	2007	3	1301.0	9	3903.0	27	937.17
17.	2008	4	470.4	16	1881.6	64	928.12
18.	2009	5	531.1	25	2655.5	125	919.07
19.	2010	6	768.6	36	4611.6	216	910.02
20.	2011	7	1139.6	49	7977.2	343	900.97
21.	2012	8	1113.7	64	8909.6	812	891.92
22.	2013	9	1179.0	81	10611.0	729	882.87
23.	2014	10	735.7	100	7357.0	1000	873.82
24.	2015	11	707.4	121	7781.4	1331	864.77
25.	2016	12	989.2	144	11870.4	1728	855.72
Total	**N = 25**	**$\sum X = 0$**	**$\sum Y = 24108.1$**	**$\sum X^2 = 1300$**	**$\sum XY = -11765.4$**	**$\sum X^3 = 0$**	

Table 5.Computation of Future Rainfall Trend Value of Thandla area, Jhabua district

S. No.	Year	Expected trend value rainfall (in mm.)
1.	2017	846.67
2.	2018	837.62
3.	2019	828.57
4.	2020	819.52
5.	2021	810.47
6.	2022	801.42
7.	2023	792.37
8.	2024	783.32
9.	2025	774.27

Figure 7 Future Forecast of Expected Rainfall in Thandla Area, Jhabua District



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Environmental Implications

Environmental scenario is immensely affected by the hydrometeorological and meteorological parameters, namely rainfall and temperature respectively. The amount and frequency of rainfall are main factors for the recharge of ground water. The positive trend of adequate rainfall indicates good conditions for recharge of ground water system. The excess rainfall generates situation of chaos resulting into river flooding, growth of vegetation, crops, forest, and communication distortion of building structures and others. The negative trend, scarcity and low intensity of rainfall considerably affect the recharge phenomenon generating sustained supply of water for the agriculture development, human and animal kingdoms, even causing drought conditions.

The analyses of rainfall data indicate both positive and negative trends that point out environmental problems to the Thandla inhabitants. The present trend of rainfall is indicating negative trend with respect to the annual rainfall values. This is causing conditions of sustained water supply to the inhabitants of Thandla area. It is suggested that implementation of a scheme for development of aforestation, augmentation of ground water recharge, would resolve the present water crisis in the study area.

Conclusion

Thandla rainfall data for a period of 25 years have been treated with Mathematical and Statistical techniques of analyses. Computation indicates a range from 423.00 to 2086.20 mm and annual average as 964.32 mm. The departure of annual rainfall from the average value, and cumulative departure have been determined. The statistical analysis of rainfall data has revealed that mean (976 mm), median (960), mode (1140), standard deviation (412 mm.), co-efficient of dispersion (0.422), co-efficient of variation (42.213), and co-efficient of skewness (-0.398). The analyzed values indicate a negative trend of rainfall. The forecasting values are also indicating negative trend. The environmental measures for augmentation of rainfall have been suggested for implementation of a scheme for recharge of ground water system by increasing amounts and frequencies of rainfall by aforestation.

Acknowledgement

The appreciation is recorded to Professor K. N. Singh, Professor and Head, School of Studies in Earth Science, Vikram University, Ujjain. One of the authors (A. Katara) is obliged to the Government of India for the award of Rajeev Gandhi National Fellowship. Sincere thanks are due to Professors P. K. Verma, S.K. Maanjhu; Drs. Vinod Bhuriya, Eshwar Lal Dangi, S. bamaniya; M/s Mohammad Rizwan, Pankaj Barbele, Dayaram Solanki, K. Dangi; Mrs. Aarti Dawar, D. Nigwal, P. Bariya and others for very kind assistance and cooperation.

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