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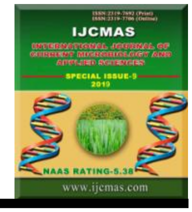

Original Research Article

Trend Analysis of Rainfall Data for Pusa Farm (Samastipur)

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A B S T R A C T

Present study examined the evolution of rainfall in Pusa farm (Samastipur, Bihar) over the last 35 years (1980 to 2014) and ascertained whether the observed time trend in rainfall during this period was statistically significant. Non-parametric Mann-Kendal (MK) test had also been employed to ascertain the presence of a statistically significant trend in rainfall. This test was used to detect that either trend is increasing or decreasing. The value of MK statistics (S) was found to be -75 and value of test statistics (Z) was -1.051. As per MKtest the magnitude of Z was less than the tabulated value from normal probability distribution table for two-tailed test. Accordingly in the present analysis of rainfall, the trend of annual rainfall data was found to be non-significant at 5% level of significance in decreasing trend due to negative value of Z (test statistics). The slope for annual rainfall data as determined using the Sen's slope estimator was found -1.18 which also revealed a negative trend in annual rainfall pattern. The slope of regression analysis for annual rainfall of Pusa Farm was found to be -1.530mm/year also signified negative trends. In nutshell, the overall annual rainfall will decrease in the upcoming years but it is not sure that this remains the same.

Keywords

Climate change, Mann-Kendall test, Sen's estimator method, Test statistics (Z), Regression analysis

Introduction

In present scenario the occurrence of climatic change is at alarming rate. Atmospheric variables like temperature, wind velocity, solar radiations etc. have taken abnormal form. The rainfall pattern has also been drastically changed, resulting into declination of water potential both surface and sub–surface, worldwide. Between 1999 and 2005, there was almost 10 percent less annual rainfall. The effect of climatic change has also created impact on extent of different seasons. From 1880 to 2012, the average global temperature increased by 0.85 °C (Fifth Assessment Report, IPCC). The IPCC predicts that increases in global mean temperature of less than 1.8 to 5.4 degrees Fahrenheit (1°C to 3°C) above 1990 levels will produce beneficial impacts in some regions and harmful ones in others. Net annual costs will increase over time as global temperatures increase. Changes in rainfall and temperatures have also been reported by Dash et al. (2009), Arora et al.(2005), De et al. (2005), Guhathakurta and Rajeevan (2008), MoEF (2010), Jones and Briffa (1992), Kothawale et al. (2010) and others.

The trend in a time series data can be

expressed by a suitable linear (parametric) or nonlinear (non-parametric) model which depends on the nature of the available data. The nonparametric test Mann-Kendall Test is commonly applied to assess the statistical significance of trends when normality is violated during application of linear model (Libiseller and Grimvall, 2002). The MK test checks null hypothesis of no trend versus the alternative hypothesis of the existence of increasing or decreasing trend. This test is used to detect that either trend is increasing or decreasing.

Mondal *et al.* (2012) used Mann-Kendall (MK) Test to find out the monthly variability of rainfall and Sen's Slope Estimator together with Modified Mann-Kendall Test was used for the determination of trend and slope magnitude. Chakraborty *et al.* (2013) analyzed 49 years of rainfall data at Seonath sub basin in Chattisgarh state (India) and observed a significant negative trend in 17% of the stations and 75% of the stations with non-significant decreasing trend with MK test and the magnitude of trend ranges between 0.1 and -13.6mm/year in the study area. Oza and Kishtawal (2014) analyzed daily gridded rainfall data for the period 1915-2010 corresponding to monsoon season and monthly rainfall data at meteorological sub-division level and concluded that there is a statistically significant decreasing trend in all India ISM rainfall.

The study examines the evolution of rainfall in Pusa farm over the last 35 years and ascertains whether the observed time trend in rainfall during this period is statistically significant.

Materials and methods

Study area

The Pusa Farm (Samastipur, Bihar) is selected for analyzing the rainfall variability, which is located at 52m above mean sea level; 25.98^0 N latitude and 85.67^0 E longitude. The climate is humid. The project area falls under humid zone of the state. The topography of area is mild to flat slope. Soil is light to heavy textured with more than 25% $CaCO_3$ in the form of silt and clay fractions. The topography of the area is about to flat. The Burhi Gandak River is located adjacent to Pusa farm, acts as outlet for draining the rainwater from entire region.

The daily rainfall data of 35-years (1980-2014) was collected from Agro-meteorology department located at R.A.U., Pusa for study purpose.

Trend analysis

The trend analysis of time series is done by determining the magnitude of trend as well as its statistical significance. The magnitude of trend in a time series is determined by two methods either Sen's estimator method (non-parametric method) or using regression analysis (parametric method). Both methods assume a linear trend in time series analysis. Non-parametric Mann-Kendal test has been employed to ascertain the presence of statistically significant trend in rainfall.

Mann-Kendal Test

The MK test checks null hypothesis of no trend versus the alternative hypothesis of the existence of increasing or decreasing trend. This test is used to detect that either trend is increasing or decreasing. The MK test does not require assuming normality.

The Mann-Kendal test statistic S is defined as

$$S=\sum_{i=1}^{N-1}\sum_{j=i+1}^{N} sgn(x_j-x_i) \quad \ldots (1)$$

Assuming $(x_j - x_i) = \theta$

Then $sgn\theta = \begin{cases} +1 \; if \; \theta > 0 \\ 0 \; if \; \theta = 0 \\ -1 \; if \; \theta < 0 \end{cases}$

For large samples (N>10) it is considered using normal approximation (Z statistics) with mean and variance:

$$E[S] = 0 \qquad \dots (2)$$

$$var(S) = \frac{1}{18}\left[N(N-1)(2N+5) - \sum_{p=1}^{q} t_p(t_p - 1)(2t_p + 5)\right] \qquad \dots (3)$$

Where q is the number of tied (zero difference between compared values) groups, and t_p is the number of data values in the p^{th} group. The standard normal deviate (Z-statistics) is then computed as:

$$Z = \begin{cases} \frac{S-1}{\sqrt{var(S)}} & if \; S > 0 \\ 0 & if \; S = 0 \\ \frac{S+1}{\sqrt{var(S)}} & if \; S < 0 \end{cases} \qquad \dots (4)$$

Z value evaluates the statistically significant trend. A positive value of Z shows an upward trend and its negative value shows downward trend. To test either trend is monotonic or not a two-tailed test is applied at α level of significance, null hypothesis is rejected if the absolute value of Z is greater than $Z_{\alpha/2}$, where $Z_{\alpha/2}$ is obtained from the standard normal cumulative distribution tables. In this analysis the null hypothesis was tested at 5% of significance level.

Sen's Slope Estimator

The Sen's estimator has been widely used for determining the magnitude of trend in hydro-meteorological time series. In this method the slopes T_i of all data pairs of linear trend is calculated using the equation:

$$T_i = \frac{x_j - x_k}{j-k} \quad for \; i = 1,2,3, \dots, N \qquad \dots (5)$$

Where x_j and x_k are data values at time j and k (j>k) respectively. The median of these N values of T_i is Sen's estimator of slope. The N values of T_i are ranked from the smallest to the largest and Sen's estimator of slope is calculated by:

$$\beta = \begin{cases} T_{\frac{N+1}{2}} & N \; is \; odd \\ \frac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+2}{2}}\right) & N \; is \; even \end{cases} \qquad \dots (6)$$

A positive value of β indicates an upward or increasing trend and a negative value indicates a downward or decreasing trend in the time series.

Regression Analysis

Regression analysis is the most useful parametric models used to develop functional relationships between dependent and independent variables are the "simple regression" model. A linear equation *y*= *mt* + *c* , defined for rainfall value *y* and *t* as time in year, *c* (least square estimates of the intercept) and the trend *m* (slope), can be fitted by regression.

The linear trend value represented by the slope of the simple least-square regression line provides the rate of rise/fall in the variable. If the slope is statistically significantly different from zero, the interpretation is that, it is reasonable to interpret. The positive sign of slope indicates an increasing trend and its negative value shows decreasing trend.

Results and Discussion

The MK test was used for trend analysis of annual rainfall data of Pusa Farm using the software XLSTAT. The value of MK statistics (S) was found -75 and value of test statistics (Z) was -1.051. As per MK test the magnitude of Z is less than the tabulated value from normal probability distribution table (i.e. 1.96) for two-tailed test the trend is in decline form. Accordingly, in present analysis of rainfall the trend of annual rainfall data was found to be non-significant at 5% level of significance in decreasing trend due to negative value of Z (test statistics).

The slope of regression analysis (linear trend) for annual rainfall of Pusa Farm was found to be -1.530mm/year also signified negative trends. The regression curve showing trend of annual rainfall is illustrated in Fig 1.

The result of the analysis to estimate the Sen's slope is shown in table 1. The slope for annual rainfall data as determined using the Sen's slope estimator was found -1.18 which also reveals a negative trend in annual rainfall pattern. The detailed computation for determining the slope of rainfall is shown in table 2.

The present study was done to know the rainfall variability in Pusa region from 1980 to 2014. The collected rainfall data were analyzed to know the rainfall trend. The result of the study showed that the overall annual rainfall will decrease in the upcoming years but it is not sure that it remains same. So there may be a chance of drought in Pusa region in future. This information may help the hydrologists to plan the regional constructions as desired so that sustainability will be balanced in future.

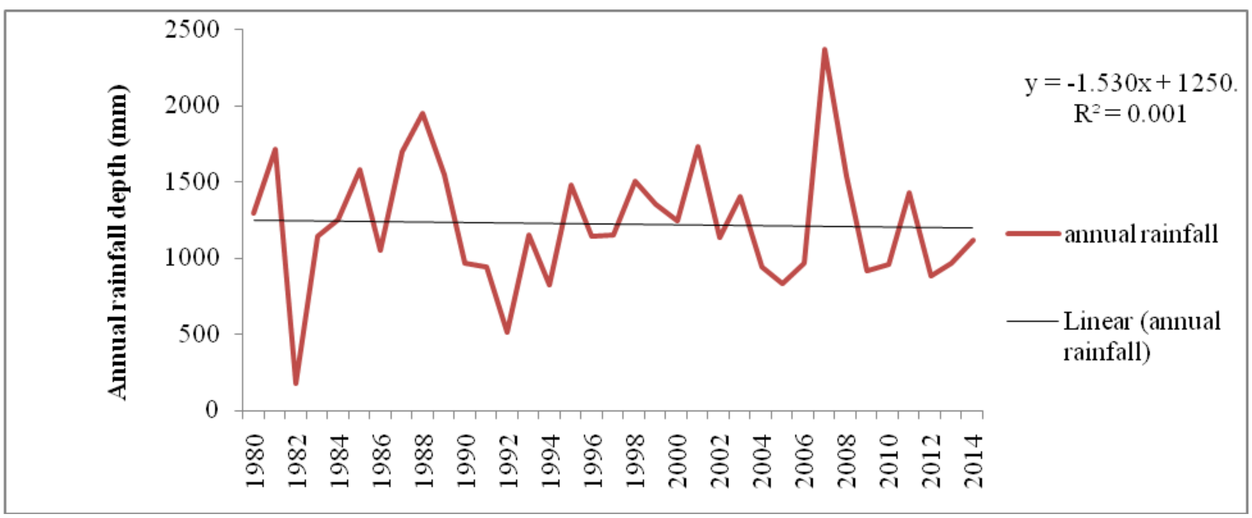

Fig.1 Trend of Annual Rainfall Variation (1980-2014)

Table.1 Mann-kendall test statistics of annual rainfall data (1980-2014)

Sl No.	Year	Rainfall (mm)	S
1	1980	1295	-8
2	1981	1715.4	-27
3	1982	174.7	32
4	1983	1140	3
5	1984	1252.2	-6
6	1985	1574.1	-21
7	1986	1044.71	6
8	1987	1697.4	-21
9	1988	1951.5	-24
10	1989	1544.1	-21
11	1990	967.1	4
12	1991	942.9	13
13	1992	509.8	22
14	1993	1146.7	-1
15	1994	824.2	20
16	1995	1475.9	-11
17	1996	1140.1	0
18	1997	1151.8	-1
19	1998	1504.6	-10
20	1999	1348	-5
21	2000	1243.9	-4
22	2001	1732	-11
23	2002	1129	-4
24	2003	1401.5	-5
25	2004	943.3	4
26	2005	827.7	9
27	2006	964.2	0
28	2007	2367.9	-7
29	2008	1535	-6
30	2009	911.4	3
31	2010	957.4	2
32	2011	1428.5	-3
33	2012	880.2	2
34	2013	961.2	1
35	2014	1112.4	0
N		S	-75
35		Variance	4958.33
		Z	-1.051

Table 2: Sen's slope estimator test of annual rainfall

Sl No.	Year	Rainfall (mm)						
1	1980	1149.6	406.2					
2	1981	1555.8	-660.1875	-1066.3875				
3	1982	93.3	-60.1394	-296.6884	639.9167			
4	1983	970.9	-4.6066	-146.9653	454.3	175.875		
5	1984	1131.7	43.2917	-52.2105	395.0312	211.3672	246.8594	
6	1985	1357.4	-64.7133	-164.6039	166.8601	-69.6682	-192.4398	-631.7391
7	1986	779.81	62.125	0.9949	291.9517	161.4648	156.6615	111.5625
8	1987	1561.4	20.5	-34.6	190.6719	68.1506	44.2118	-13.6875
9	1988	1313.6	10.141	-39.9025	156.7754	45.2813	21.5369	-28.5347
10	1989	1240	-29.0276	-78.3252	93.6979	-15.5458	-44.9952	-98.0597
11	1990	864.3	-28.2048	-72.7918	82.3922	-15.9945	-41.5771	-85.9519
12	1991	846.6	-61.4816	-105.366	33.767	-61.9408	-89.9191	-134.8229
13	1992	432.9	-9.341	-43.8872	81.7775	5.6676	-11.3531	-40.0434
14	1993	1027.9	-33.4365	-67.404	47.809	-26.2044	-44.5753	-73.7188
15	1994	683.4	15.5279	-12.6649	97.0797	34.4447	22.6589	2.277
16	1995	1380.3	-5.7636	-33.6528	68.123	6.8594	-6.1418	-27.2253
17	1996	1058.7	-7.8271	-34.2222	61.3627	3.5073	-8.8047	-28.4712
18	1997	1019	10.8068	-13.012	77.9063	25.2178	15.174	-1.375
19	1998	1339.8	5.0813	-17.2385	66.3561	17.1938	7.5767	-7.8609
20	1999	1246	-6.4217	-28.27	50.7828	3.0152	-6.8625	-22.2396
21	2000	1021.9	18.1923	-1.404	74.724	31.2476	23.4299	10.6625
22	2001	1528	-6.7743	-26.711	45.2017	1.686	-7.2468	-20.9823
23	2002	1002.5	2.1168	-16.5661	52.5095	11.5276	3.5107	-8.9688
24	2003	1197.5	-16.775	-35.1652	29.183	-10.6474	-19.1257	-31.7917
25	2004	747	-17.244	-34.8875	26.7179	-11.4578	-19.5697	-31.6287
26	2005	718.5	-11.7077	-28.424	30.8156	-5.4584	-12.9554	-24.1604
27	2006	845.2	39.8815	25.7923	83.9803	52.2503	47.3603	39.1441
28	2007	2226.4	10.8179	-3.8259	51.4848	19.242	13.3033	4.0991
29	2008	1452.5	-17.0103	-32.125	20.5474	-12.0867	-18.9295	-28.9711
30	2009	656.3	-20.72	-35.4414	15.3063	-16.3864	-23.1176	-32.9127
31	2010	528	1.9742	-11.5	38.0102	8.5591	2.9173	-5.5954
32	2011	1210.8	-11.3594	-24.829	22.7895	-6.3661	-12.2927	-21.0037
33	2012	786.1	-10.4424	-23.4625	22.6656	-5.5247	-11.2213	-19.5887
34	2013	805	-4.5206	-16.9667	27.858	0.8057	-4.5095	-12.3801
35	2014	995.9						

Sl No.	Year									
8	1987	-180.6875								
9	1988	-140.6125	-80.5							
10	1989	-217.8437	-245.7109	-410.9219						
11	1990	-173.7361	-170.2604	-215.1406	-19.3594					
12	1991	-224.4176	-240.8164	-294.2552	-235.9219	-452.4844				
13	1992	-83.3594	-56.8153	-51.5521	51.125	79.3187	433.8542			
14	1993	-120.0391	-106.0433	-110.6875	-43.9688	-51	109.5938	-376.7969		
15	1994	-22.0087	9.7271	23.6082	102.6136	129.7187	296.0625	192.7188	762.2344	
16	1995	-54.9828	-32.7996	-26.4396	32.7115	42.179	152.1042	11.2292	205.2422	-351.75
17	1996	-53.9318	-33.9178	-28.4375	22.5604	29.0096	116.554	-2.4336	122.3542	-197.5859
18	1997	-20.1979	2.7292	11.4901	61.1857	71.925	152.6034	68.2281	179.4844	-14.7656
19	1998	-25.5532	-6.1615	0.5966	41.7484	48.5382	111.166	36.6995	111.8807	-32.6424
20	1999	-40.695	-24.5421	-19.8789	15.6705	19.1734	71.5799	-0.875	56.9591	-71.2727
21	2000	-2.3569	16.75	24.2308	60.4935	67.7528	119.7766	64.3511	123.1708	24.8534
22	2001	-37.0483	-22.6844	-18.5547	11.6274	14.2096	56.6364	-2.9243	41.0607	-55.0958
23	2002	-22.7438	-7.9365	-3.099	26.0313	29.5228	69.6901	17.6667	59.1891	-23.5221
24	2003	-46.8816	-35.4125	-32.6799	-8.2772	-7.5129	25.4479	-25.6029	6.3239	-69.2672
25	2004	-45.881	-35.0059	-32.4201	-9.6102	-8.985	21.4047	-25.8449	3.1744	-65.2479
26	2005	-36.972	-26.0222	-23.107	-1.1811	-0.0918	28.746	-14.0848	13.4194	-48.0218
27	2006	32.6438	48.0421	54.5403	79.3236	84.8735	116.8948	85.7822	118.1729	69.6788
28	2007	-5.0956	6.945	11.134	32.3695	35.1101	62.3881	28.3607	54.7124	5.4935
29	2008	-40.4579	-31.3	-29.0605	-10.8495	-10.4233	12.8814	-23.2665	-1.7998	-51.1919
30	2009	-44.2164	-35.7091	-33.7669	-16.6721	-16.5445	5.1846	-29.4554	-9.6779	-56.284
31	2010	-14.3857	-4.4696	-1.3221	16.3664	17.9788	40.2164	10.1773	30.9196	-10.5
32	2011	-30.558	-21.9792	-19.6615	-3.5271	-2.8461	17.3624	-12.7455	5.6875	-34.6617
33	2012	-28.6826	-20.344	-18.0605	-2.5592	-1.8691	17.4344	-11.1609	6.3808	-31.7094
34	2013	-20.6602	-12.2192	-9.7306	5.4444	6.4195	25.1982	-1.5259	15.5805	-20.0806
35	2014									

Sl No.	Year										
17	1996	-43.4219									
18	1997	153.7266	350.875								
19	1998	58.5313	99.3125	-68.3958							
20	1999	-8.9444	0.9062	-139.0813	-245.1094						
21	2000	93.3267	123.7153	58.8125	154.2187	553.5469					
22	2001	-9.4567	-3.2813	-81.9826	-88.776	-10.6094	-574.7656				
23	2002	20.2417	30.0361	-28.2983	-13.2617	64.0208	-180.7422	213.2812			
24	2003	-37.8802	-37.1875	-92.625	-99.233	-66.816	-244.0625	-111.7812	-328.4896		
25	2004	-36.8638	-36.1426	-83.9595	-87.5	-59.324	-192.7381	-86.4348	-201.988	-28.5	
26	2005	-20.8729	-18.6595	-58.881	-57.0244	-28.8995	-131.3077	-36.7033	-104.4958	49.1	126.7
27	2006	103.9936	117.0609	94.3191	122.1139	169.3072	112.6452	231.5486	235.3693	493.1333	753.95
28	2007	32.2033	38.3144	10.8365	22.8718	53.0669	-10.4861	71.5909	47.4734	176.375	244.6667
29	2008	-30.419	-29.4536	-59.9561	-58.802	-40.1129	-106.3049	-47.5176	-84.9417	-18.14	-15.55
30	2009	-37.2982	-36.8777	-65.4677	-65.1036	-48.8319	-108.6957	-57.2672	-90.8236	-36.5	-38.1
31	2010	9.9878	13.3992	-9.6269	-2.9264	16.9961	-31.098	22.4323	1.5887	66.2571	82.05
32	2011	-16.7975	-15.208	-38.4514	-35.2993	-19.4646	-66.2411	-21.0389	-43.8994	4.8875	9.6571
33	2012	-14.7255	-13.1173	-34.7273	-31.4358	-16.5392	-59.2623	-17.5	-37.8444	6.4444	10.8125
34	2013	-3.4451	-1.3342	-20.9695	-16.6416	-1.8421	-40.3106	-0.5372	-17.7286	24.89	30.8222
35	2014										

Sl No.	Year								
27	2006	627.25							
28	2007	303.65	-773.9						
29	2008	-62.9667	-785.05	-796.2					
30	2009	-79.3	-566.1333	-462.25	-128.3				
31	2010	73.12	-253.9	-80.5667	277.25	682.8			
32	2011	-9.85	-288.06	-166.6	43.2667	129.05	-424.7		
33	2012	-5.7429	-236.9	-129.5	37.175	92.3333	-202.9	18.9	
34	2013	18.8375	-175.7857	-76.1	67.92	116.975	-71.6333	104.9	190.9
35	2014								

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