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Impact of Climate Change on Rainfall Pattern in Lower Ganges Basin

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Abstract:
The present study has been taken up the statistical analysis of different hydrological changes of monthly and annual rainfall. In this paper we estimate and workout the probability of exceedance, return period, standard deviation, runoff and percentage deviation of rainfall of lower Ganges basin area for the period of 1901-2011(110 years). The data is collected from IMD (India Meteorological Department) and IITM (Indian Institute of Tropical Meteorology), Pune. This paper consists of the statistical analysis on the assessment of the recent researches of IPCC (Inter Governmental Panel on Climate Change), CPCB (Central Pollution Control Board), CWC (Central Water Commission) and WMO (World Meteorological Organization) etc. Comparative study of climate change of lower Ganges basin with entire India is also included in this paper.

Keywords:
Annual rainfall, Climate change, Statistical analysis, lower Ganges basin.

INTRODUCTION:
The Ganges River is one of the prime river of India. The Ganges flows east through the Gangatic plain of northern Indian into the country of Bangladesh. The Ganges originates as Bhagirathi from the Gangotri glaciers in the Himalayas of an elevation of about 7010 Metres. in Uttarkashi district of Uttarakhand. After its confluence with the Alakananda at Devprayag, the river assumes the name of Ganges and flows for the total length of about 2525 K.M. up to its outfall into the Bay of Bengal. The basin is divided into (1) Upper Ganges Segment (Gangotri to Haridwar) (2) Middle Ganges (Haridwar to Varanasi) and (3) Lower Ganges plain (Varanasi to Gangasagar) drainage system. The lower Ganges plain drainage system is constituted by the tributaries and distributaries of the main Ganges where Padma and Bhagirathi being the most important of Ganges. The Hoogly - Bhagirathi act as main stream in the lower Ganges plain which joins the Bay of Bengal near the Sagar Island.

The study area is Varanasi to Sagar Island having Latitude 21.72690 N - 25.316760 N and Longitude 82.97390 E - 88.10960 E.The main objective of this paper 1.It gives the guideline of the future researcher and designer of irrigation and drainage projects. 2. It helps the planner for water resource development project.

Materials and Method:
The present study is based on the rainfall data collected for 110 years from IMD and IITM Pune.

i) Estimation of Mean, Standard deviation and Percentage deviation:
Mean $X0=(X_1+X_2+X_3+\ldots\ldots\ldots\ldots\ldots+X_n)/n$, $x_1,x_2,x_3\ldots\ldots\ldots x_n$ = Annual rainfall, n= Total number of observation,

Standard Deviation, $\sigma=\sqrt{[\sum(x-x0)^2/n-1]}$
The Intensity of drought is determined using the criteria suggested by IMD (1971)

which is based on percentage deviation of rainfall from its long term mean and it is
given by $Di = (Pi - \mu)/\mu \times 100\ \%$
D_i = Percentage deviation,
P_i = Annual rainfall in mm,
μ = Long term mean of Annual rainfall in mm,

ii) Probability of exceedance (Px):
The probability of exceedance refers to the probability of occurrence is expressed as a faction or as a percentage change with a scale ranging from zero to 100 percentage. It is estimate by using Girngorten formula (WMO, 1983).

$Px = [(r-o.44) / (n+o.12)] \times 100\ \%$
r = Rank number of observed data, listed with descending order (high to low)
n = Total number of observation.

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iii) Return period or Recurrence interval (ICTP – 2013):

It is expressed in number of years in which the annual observation is expected to return. It is the reciprocal value of the probability when expressed as a fraction

$Tx = 1/p_x$

iv) Determination of weather condition:

ICTP - 2013 and Guide line of WMO No. 100 - 1990, FAO (Smith 1992) uses the following rules for the determination of dry, Normal and humid weather condition:

1. The weather condition in a Period is called dry if the probability of exceedance of having 80%.
2. The rainfall in a period is called normal if the probability of exceedance is equal to 50%.
3. The weather condition in a period is called humid if the probability of exceedance having 20%.

Result and Discussion:

Studies related to changes in rainfall both all over India and Lower Ganges basin have shown that there is no clear trend of increase or decrease in annual average rainfall (Mooley and Parthasarathy 1984, Sarkar and Thapliyal 1988, Thapliyal and Kulshrestha,1991).

The examination of trend of annual rainfall both Lower Ganges basin and all over India have indicated that 10 years running mean has fluctuated from normal rainfall within (-)8.40 to (+)9.99%(Lower Ganges basin, reference table-1A and (-)8.12% to (+) 5.90% (all over India, reference table-2).

• In table – 1A, Percentage deviation up to (-) 19% represents no drought (ND), (-) 20% to (-) 59% represents Medium drought (MD) and - 60% and above deficiency represents severe drought.

• From statistical analysis, in lower Ganges basin (table – 1B) we found that in the year of (i) 1932 for the period of 1931 to 1941. (ii) 1965 & 1966 for the period for the period of 1961 to 1970. (iii) 1971 and 1979 for the period of 1971 to 1980 (iv) 1992 for the period of 1991 - 2000 occurs medium drought and mean 1229.56 mm.

• But when we observe all India data (Table - 2), there are no drought, mean is 1179.98 mm and Standard Deviation is 48.52mm.

• In table - 3, here we analyzed and estimate for the period of 1961-2006 (46 Years) data; we found that different probabilities and return period changes the climate.

Statistical analysis:

Lower Ganges basin Table -1A

• Mean , Standard Deviation and Percentage Deviation-

Period	Short term annual mean rainfall (mm)	Long term annual mean rainfall (mm)	Standard Deviation (mm)	Percentage Deviation %	Remarks
1901-1910	1161.3	1229.56	70.42	- 5.55	D R
1911-1920	1352.4	1229.56	70.42	+9.99	-
1921-1930	1247.7	1229.56	70.42	+1.47	-
1931-1940	1242.9	1229.56	70.42	+1.08	-
1941-1950	1272.4	1229.56	70.42	+3.48	-
1951-1960	1193.9	1229.56	70.42	-2.90	D R
1961-1970	1126.4	1229.56	70.42	-8.40	D R
1971-1980	1207.1	1229.56	70.42	-1.82	D R
1981-1990	1224	1229.56	70.42	-0.45	D R
1991-2000	1330.2	1229.56	70.42	+8.18	-
2001-2006	1166.9	1229.56	70.42	-5.09	D R

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- D R = Deficiency of rainfall.
- Data source : www.tropmet.res.in/pub/data/rain-series/3-nci.txt

Intensity of drought analysis: Table- 1B

period	Year	Annual Rainfall mm	Long term annual mean rainfall (mm)	Percentage deviation %	Intensity of drought
1931-1941	1932	969.5	1229.56	-21.15	M D
1961-1970	1965	874.2	1229.56	-28.90	M D
	1966	868.7	1229.56	-29.35	M D
1971-1980	1972	948.1	1229.56	-22.89	M D
	1979	835.4	1229.56	-32.06	M D
1991-2000	1992	960.5	1229.56	-21.88	M D

- M D = Medium drought.
- Data source: www.tropmet.res.in/pub/data/rain-series/3-nci.txt.

All India Rainfall data analysis: Table-2

period	Short term annual mean rainfall (mm)	Long term annual mean Rainfall (mm)	Standard deviation	Percentage deviation %	Remarks
1901-1910	1084.15	1179.98	48.52	-8.12	D R
1911-1920	1160.73	1179.98	48.52	-1.63	D R
1921-1930	1207.59	1179.98	48.52	+2.34	-
1931-1940	1234.27	1179.98	48.52	+4.60	-
1941-1950	1249.6	1179.98	48.52	+5.90	-
1951-1960	1218.8	1179.98	48.52	+3.23	-
1961-1970	1168.4	1179.98	48.52	-0.98	D R
1971-1980	1158.46	1179.98	48.52	-1.82	D R
1981-1990	1197.91	1179.98	48.52	+1.52	-
1991-2000	1174.52	1179.98	48.52	-0.46	D R
2001-2010	1125.37	1179.98	48.52	-4.63	D R

- D R= Deficiency of rainfall.

Data source: IMD district rainfall data series.

Statistical analysis of probability of exceedance and return period for 1961-2006 (46 years) of lower Ganges basin.
Table - 3

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Year	Rainfall (X_p) in mm	Rank number (r)	Probability of exceedance (P_X) %	Return period / Recurrence interval(T_X) Years	Remarks on weather condition
1971	1615.2	1	1.21	82.64	Humid
1980	1454.8	2	3.38	29.58	&
1961	1435.9	3	5.55	18.01	Wet
2003	1355.1	4	7.71	12.97	
1984	1340.7	5	9.89	10.11	
1999	1334.3	6	12.05	8.29	
1990	1332.8	7	14.22	7.03	
1973	1319.1	8	16.39	6.10	
1985	1315.5	9	18.56	5.39	
1997	1315.4	10	20.73	4.82	
1994	1314.9	11	22.89	4.37	
1978	1312.6	12	25.06	3.39	
1970	1273.0	13	27.23	3.67	
2001	1262.4	14	29.40	3.40	
1998	1257.4	15	31.57	3.17	
1981	1255.1	16	33.73	2.96	
1975	1245.2	17	35.90	2.78	Semi humid
1977	1236.2	18	38.07	2.63	
1995	1219.8	19	40.24	2.48	
1983	1212.9	20	42.41	2.36	
1987	1193.3	21	44.58	2.24	
1964	1179.4	22	46.75	2.14	
1963	1177.3	23	48.91	2.04	
2000	1170.2	24	51.08	1.96	
1969	1168.2	25	53.25	1.88	Normal
1986	1167.8	26	55.42	1.80	
1967	1159.4	27	57.59	1.57	
2005	1154.2	28	59.76	1.67	
1988	1146.7	29	61.92	1.61	
1989	1144.2	30	64.09	1.56	
1993	1140.6	31	66.26	1.50	
1996	1136.8	32	68.43	1.46	Semi dry
1982	1130.7	33	70.59	1.42	
2006	1129.3	34	72.74	1.37	
1991	1119.0	35	74.93	1.33	
1962	1090.0	36	77.10	1.29	

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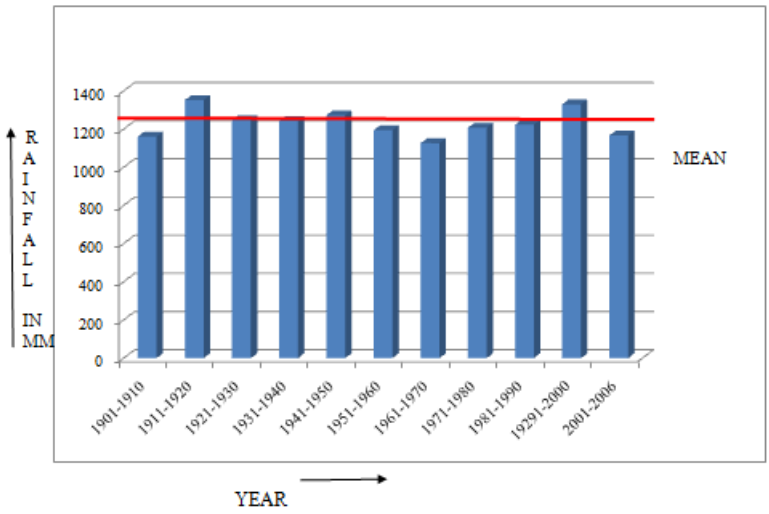
2004	1072.0	37	79.27	1.26	
1976	1069.8	38	81.44	1.23	
1968	1039.1	39	83.60	1.19	
1974	1035.0	40	85.78	1.16	
2002	1028.5	41	87.94	1.14	
1992	960.5	42	90.11	1.11	Dry
1972	948.1	43	92.28	1.08	
1965	874.2	44	94.45	1.06	
1966	868.7	45	96.62	1.03	
1979	835.4	46	98.76	1.01	

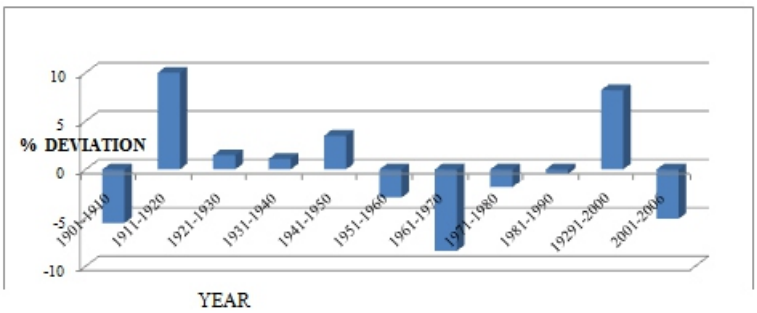
Data source: www.tropmet.res.in/pub/data/rain-series/3-nci.txt.

Graphical representation of Rainfall Vs Time Period (1901-2006) of lower Ganges basin:
Reference from table-1A. Graph- 1



Graph shows the Percentage deviation of Rainfall Vs Time period (1901-2006) of lower Ganges basin:

From reference table- 1A, Graph- 2



Graphical representation of Rainfall Vs Time Period (1901-2006) of entire India:

Reference from table-2 Graph- 3

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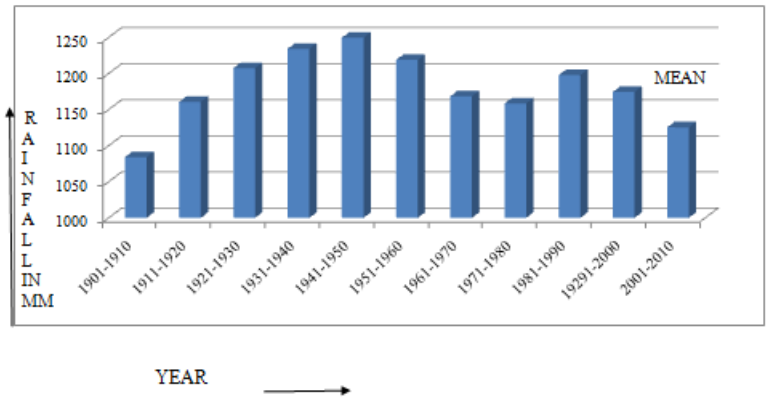
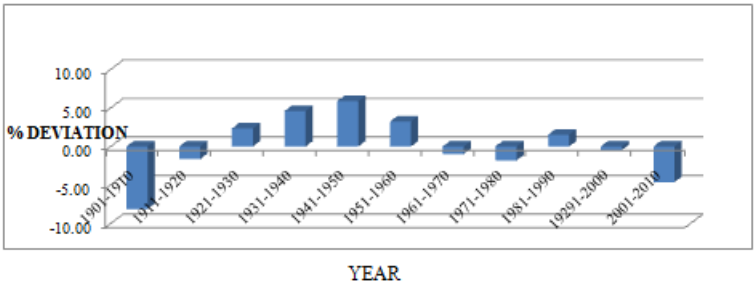


Graph shows the Percentage deviation of Rainfall Vs Time period (1901-2006) of entire India:

From reference table- 2, Graph- 4,



Conclusion:

From the study (110 years analysis), we found that the normal rainfall of lower Ganges basin fluctuates in between 835.4mm to 1615.2mm and annual mean rainfall 1229.56mm and no drought occurs in maximum years. Moderate drought has found in few years which is a natural trend. From the analysis, we observed that last few decades rainfall in this area is decreases or deviates with respect to long term mean and rainfall changes the weather condition. The result suggested that the proper planning development and management of water resources need to be governed by national perspectives.

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