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Future monthly, seasonal and annual rainfall trend prediction for *Tarai* region of Uttarakhand

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***Abstract**: In this study, trend analysis of rainfall on monthly, seasonal (monsoon, winter and summer)and annual basis for Tarai region of Uttarakhand was conducted by considering long-term daily rainfall dataset of 53 years (1961-2013) recorded at G.B. Pant University of Agriculture & Technology, Pantnagar. The positive trend of departure from mean value of rainfall on time basis shows groundwater reservoir recharge, whereas, negative trend implies extraction from aquifers. During last few years, recorded values of rainfall on monthly, seasonal and annual basis showed positive trend at study area which was further strengthened by different statistical indices. The expected future trend of rainfall occurrence on monthly, seasonal and annual basis for next 12 years indicated a positive trend.*

***Keywords**: Rainfall, trend, prediction, statistical analysis.*

I. Introduction

Rainfall, a continuous random variable, is one of the most important natural input resources for crop production and its non-availability of certain amount at critical growth stages can influence failure of crops and various agricultural related issues. The marginal and small farmers constituting 80% of agricultural income group still depend on rainfed farming. In our country, rainfall distribution is very erratic in nature and varies from region to region and year to year though adequate rainfall is received through four different types of weather phenomenon namely, south-west monsoon (about 74%), north-east monsoon (about 3%), pre-monsoon (about 13%) and post-monsoon (about 10%) with an average annual rainfall as 119 cm. Since crop yields are strongly related to growing season rainfall, successful trend prediction for periods of one to three years in advance would be helpful to plan crops and estimate future yields and, thereby, emphasis was placed to predict future rainfall trend in this study with widely acclaimed straight line method of least square fitting.

II. Materials and Methods

The long-term daily rainfall data of *Tarai* region of Uttarakhand for a period of 53 years (1961-2013) collected from the Meteorological observatory situated at Crop Research Centre of the Govind Ballabh Pant University of Agriculture & Technology, Pantnagar was analyzed by using mathematical and statistical techniques. The mathematical procedure involved calculation of mean value of rainfall on monthly, seasonal and annual basis to evaluate its departure in order to understand rainfall pattern over a longer period of time.

The most commonly used mathematical method to understand rainfall variability is to calculate its arithmetic mean. Being the mean of a particular distribution is mostly affected by extreme values, therefore, in addition to its mean value, median and mode of rainfall values were also calculated. Similarly, the statistical method employed for analyzing rainfall data of study area includes determination of mean, median, mode, standard deviation, coefficients of Dispersion, Variation, Skewness and Kurtosis [2].

The time series analysis generates valuable information regarding trend of a series of observations which can be defined as systematic increase or decrease over a period of time. It also helps to measure deviation from trend and gives an idea regarding nature of trend and is used as a tool to predict future behavior of trend. Based on time series analysis proposed by [1], prediction of future rainfall trend on monthly, seasonal and annual basis for next 12 year period (2014-2025) is being presented. The standard method of least square fit of straight line has been used to conduct trend analysis for different months, seasons (monsoon, winter and summer) and annual rainfall. The straight-line equation can be represented as, $Y = aX + b$, where Y is trend value of dependable variable, X is independent variable and a, b are unknowns. To establish a best fit straight line, values of “a” and “b”, the equation parameters must be determined from the observed data.

III. Results and Discussion

The variation in monthly rainfall for the study period on the basis of mathematical analysis is presented in Table 1. The values of different statistical parameters namely, mean, median, mode, standard deviation, coefficients of Dispersion, Variation, Skewness and Kurtosis obtained through different mathematical formulae [2] is presented in Table 2 from which it is clear that mean annual rainfall of study area was 1454.72 mm, whereas, computed value of median (1442.86 mm) and mode (927.27 mm) indicates ideal rainfall at the study area. The calculated value of Standard Deviation reveals that deviation of rainfall is 426.60 mm over a period of 53 years. The coefficient of Variation indicates that amount of rainfall varies up to 29.325 with coefficient of Skewness (1.2364) showing positive trend, whereas, coefficient of Kurtosis (1.0236) confirms that annual distribution is relatively a peaked one. For time series analysis, straight line equations obtained for different months, seasons and years is shown in Table 3. With the help of these developed equations, future forecast of rainfall amount for twelve year period (2014-2025) on monthly (Table 4a), seasonal and yearly basis (Table 4b) was being done.

IV. Conclusions

The rainfall data analysis of *Tarai* region for a period of 53 years (1961-2013) reveals strong variation in amount and frequency of rainfall and points out a positive trend of rainfall in future for all the months (except January), seasons (monsoon, winter and summer) and years. The impact of rainfall variation on monthly, seasonal and annual basis in recharge phenomena of groundwater system in *Tarai* region of Uttarakhand for next 12 years is also being presented in this paper.

References

[1] F.E. Croxton and D.J. Cowden, Applied General Statistics, Prentice-Hall of India (Private) Limited, New Delhi, 1966, pp. 302-10.
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Table 1: Average values of monthly and seasonal rainfall (1961-2013)

Season(s)	Months	Mean monthly rainfall (mm)	Percent of mean annual rainfall (%)	Mean seasonal rainfall (mm)
Monsoon	July	430.33	28.70	288.79
	August	423.79	28.26	
	September	259.12	17.28	
	October	41.92	2.80	
Winter	November	3.89	0.26	20.00
	December	13.06	0.87	
	January	27.43	1.83	
	February	35.61	2.37	
Summer	March	17.18	1.15	66.11
	April	15.17	1.01	
	May	44.88	2.99	
	June	187.22	12.48	

Table 2: Statistical parameters of rainfall on seasonal and annual basis (1961-2013)

Statistical parameters	Mathematical formulae	Computed rainfall values for			
		Monsoon	Winter	Summer	Annual
Mean ($\bar{x}$, mm)	$\frac{1}{N}\sum_{i=1}^{N} f_i x_i$	1160.38	82.55	266.04	1454.72
Median (mm)	$l + \frac{N-2C}{2f} \times h$	1108.33	72.37	239.13	1442.86
Mode (mm)	$l + \frac{f_m - f_1}{2f_m - f_1 - f_2} \times h$	730.00	54.17	210.00	927.27
Standard Deviation (mm)	$\sqrt{\frac{\sum fd^2}{\sum f} - \left(\frac{\sum fd}{\sum f}\right)^2} \times h$	433.65	56.13	185.25	426.60
Coefficient of Dispersion	$\frac{Standard\ Deviation}{Mean}$	0.3737	0.6799	0.6963	0.2933
Coefficient of Variation	$Coefficient\ of\ Dispersion \times 100$	37.3715	67.9976	69.6337	29.3252
Coefficient of Skewness	$\frac{Mean - Mode}{Standard\ Deviation}$	0.9925	0.5056	0.3025	1.2364
Coefficient of Kurtosis	$\left\{\frac{n(n+1)}{(n-1)(n-2)(n-3)} \sum \left(\frac{x_i - \bar{x}}{\sigma}\right)^4\right\} - \frac{3(n-1)^2}{(n-2)(n-3)}$	-0.0233	0.0424	3.7667	1.0236

$\bar{x}$ = mean; N = total frequency; C = cumulative frequency of group preceding the median group; l = lower limit of modal class; f_m = maximum frequency; f_1, f_2 = frequencies of classes preceding and following modal class; h = width of uniform class.

Table 3: Developed monthly, seasonal and annual rainfall trend equations

Period (months / seasons / Annual)	Developed trend equation
January	Y = 30.753 - 0.123X
February	Y = 22.550 + 0.484X
March	Y = 15.975 + 0.045X
April	Y = 11.984 + 0.118X
May	Y = 24.856 + 0.741X
June	Y = 149.253 + 1.406X
July	Y = 416.113 + 0.527X
August	Y = 310.473 + 4.197X
September	Y = 214.350 + 1.658X
October	Y = 36.508 + 0.200X
November	Y = 3.613 + 0.010X
December	Y = 12.898 + 0.006X
Monsoon	Y = 977.444 + 6.582X
Winter	Y = 69.814 + 0.377X
Summer	Y = 202.067 + 2.310X
Annual	Y = 1249.324 + 9.270X

Table 4a: Expected future trend of monthly rainfall (mm)

S. No.	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1.	2014	27.43	35.62	17.19	15.17	44.86	187.22	430.34	423.79	259.12	41.91	3.88	13.06
2.	2015	27.31	36.10	17.24	15.29	45.60	188.62	430.87	427.99	260.77	42.11	3.89	13.07
3.	2016	27.19	36.59	17.28	15.41	46.35	190.03	431.40	432.19	262.43	42.31	3.90	13.07
4.	2017	27.06	37.07	17.33	15.52	47.09	191.43	431.92	436.38	264.09	42.51	3.91	13.08
5.	2018	26.94	37.55	17.37	15.64	47.83	192.84	432.45	440.58	265.75	42.71	3.92	13.08
6.	2019	26.82	38.04	17.42	15.76	48.57	194.25	432.98	444.78	267.41	42.91	3.93	13.09
7.	2020	26.69	38.52	17.46	15.88	49.31	195.65	433.50	448.97	269.06	43.11	3.94	13.10
8.	2021	26.57	39.01	17.51	16.00	50.05	197.06	434.03	453.17	270.72	43.31	3.95	13.10
9.	2022	26.45	39.49	17.55	16.11	50.79	198.46	434.56	457.37	272.38	43.51	3.96	13.11
10.	2023	26.33	39.97	17.60	16.23	51.53	199.87	435.09	461.57	274.04	43.71	3.97	13.11
11.	2024	26.20	40.46	17.64	16.35	52.27	201.28	435.61	465.76	275.70	43.91	3.98	13.12
12.	2025	26.08	40.94	17.69	16.47	53.01	202.68	436.14	469.96	277.35	44.11	3.99	13.13

Table 4b: Expected future trend of seasonal and annual rainfall (mm)

S. No.	Year	Seasons			Annual
		Monsoon	Winter	Summer	
1.	2014	1155.17	80.00	264.45	1499.62
2.	2015	1161.75	80.38	266.76	1508.89
3.	2016	1168.33	80.76	269.07	1518.16
4.	2017	1174.91	81.13	271.38	1527.43
5.	2018	1181.50	81.51	273.69	1536.70
6.	2019	1188.08	81.89	276.00	1545.97
7.	2020	1194.66	82.27	278.31	1555.24
8.	2021	1201.24	82.64	280.62	1564.51
9.	2022	1207.82	83.02	282.93	1573.78
10.	2023	1214.42	83.40	285.24	1583.05
11.	2024	1221.00	83.77	287.55	1592.32
12.	2025	1227.58	84.15	289.86	1601.59