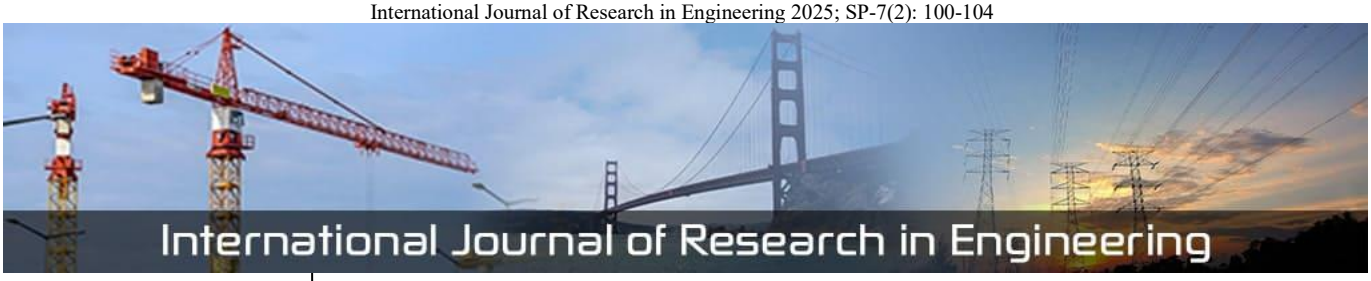

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Probability analysis for the estimation of one day annual maximum rainfall from the period 2001-2020 of Meerut city (India)

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Abstract
The rainfall data of 20 years (2001-2020) were collected from India Meteorological department, Pune. In this study, the rainfall data were analyzed for the prediction of one -day annual maximum rainfall of Meerut City by various probability distributions namely Gumbel, Ven Te Chow, Log- Pearson type-III and Log Normal had been used to determine the best probability curve using Integral Square Error (ISE). This study revealed that the Gumbel distribution was the best fit probability distribution for one -day annual maximum rainfall and Log-Pearson type-III was the second best fit for the prediction of one- day annual maximum rainfall. The result of this study would be useful for design soil and water conservation structures, irrigation, drainage system and their managements and agriculture development.

Keywords: Probability analysis, return period, integral square error, distributions, Meerut city

1. Introduction
Most part of our country received the annual maximum rainfall during June to September months (JJAS) of a year. Agriculture and cultivation among others are heavily dependent on rainfall for the better growth and development of crops and hence rainfall is the critical component of agriculture. In farming, rainfall and its pattern of observations is a serious risk factor. India received normal annual rainfall of 1170 mm approximately. Meerut receives 886 mm (34.9 inch per year) average annual maximum rainfall. The distribution of rainfall throughout the country is not uniformly distributed. The knowledge of pattern of rainfall is also an important factor for better crop planning, better development of crops, Irrigation and drainage of crops.

The frequency analysis of consecutive days maximum rainfall for different return periods have been done by (Upadhaya *et al.* (1998) [13] and Bhakar *et al.* (2006) [8], the probability analysis for one day maximum rainfall in Tamil Nadu by Manikandan *et al.* (2011) [12] and Probability analysis of annual one day maximum rainfall of Jhalarapatan area of Rajasthan for 39 years (1973- 2011) also has been done by Singh *et al.* (2012) [4]. The most commonly used probability distribution functions for the estimating the frequency of precipitation are Gumbel, Normal, Log Pearson type-III and Log Normal distribution.

In another study, the probability analysis of rainfall for the period of 1980-2013 (34 years) for the district of Allahabad of Uttar Pradesh has been investigated by Asim & Nath (2015) [3], their study showed that Gumbel distribution was found the best model for the predicting of annual maximum rainfall and Log Normal is fairly close to the observed annual rainfall (mm).

The probability of annual maximum rainfall using frequency (1991-2000) for Roorkee district of Uttarakhand has been done by Kaur *et al.* (2021) [1]. Their studies showed that the Gumbel distribution was the best model for predicting the annual maximum rainfall and second best model was VenTe Chow for the predicting the annual maximum rainfall. Analysis of Southwest monsoon rainfall over Uttar Pradesh (UP) during last two decades (2001-2020) has been done by Kant *et al.* (2023) [2]. Their study showed that east UP

experienced negative departure during 2001 to 2020 except during the years of 2003 (20%), 2008 (17%) and 2009 (2%) and highest negative percentage departure (-47%) in 2015 and west UP also experienced negative departure during 2001 to 2020 except in the years of 2003 (23%), 2008 (3%), 2010 (0%) and 2018 (1%) and highest negative percentage (-56%) in 2014. The whole UP, witnessed negative percentage departure from the normal for the years 2001 to 2020 except during 2003 (24%), 2008 (12%) and highest negative percentage departure (-47%) in 2014. Overall we can say that in the recent years the rainfall over UP remained negative side of its normal values. Hence, the rainfall analysis of Uttar Pradesh is an important scientific problem.

Motivated by the above studies, in the present study, the main purpose in this paper is to determine the prediction of annual maximum rainfall (2001-2020) in respect of Meerut for one day, two consecutive days and three consecutive days by using the various probability distribution namely Gumbel, VenTe Chow, Log Pearson type -III and Log Normal method and to select the Integral square error (ISE) for fit the best probability curve.

Rest of the paper is organized as follows. The next Section deals with the Study area, data and methodology followed by the Result and Discussion in Section 3. The paper ends with the Concluding Remarks and Recommendations in the last Section 4.

2. Study area, data and methodology

In terms of population, Uttar Pradesh is the biggest state in India. There are two meteorological observatories of India Meteorological Department (IMD) viz. Meerut city and Meerut Cant. In this study, only Meerut City (Latitude 28°N/longitude 77°E) is selected for rainfall study. The Meerut city lies 70 km northeast of the National Capital, New Delhi and 453 km northwest of the state capital, Lucknow. Meerut is surrounded by Muzaffarnagar in north, Ghaziabad, Gautam Budh Nagar and Buland Shahar in south, Jyotibaphulle Nagar and Bijnor district in the east and Baghpat district in west. In this paper, The Meerut City of Meerut district (Uttar Pradesh) is selected for rainfall study. The annual rainfall data day-wise/month-wise/year-wise of Meerut City of 20 years (2001-2020) was collected from India Meteorological Department, Pune. The annual rainfall data was tabulated and total rainfall for every year. The main motto of this paper is fixed the probability analysis of one- day annual maximum rainfall which is analyzed by the various statistical distributions like Gumbel, Ven Te Chow, Log- Pearson type-III and Log- Normal distribution. The goodness to fit was tested by Integral Square Error (ISE) method.

Arithmetic mean (average), standard deviation (σ) coefficient of variation and the coefficient of skewness

Arithmetic Mean $(\overline{X}) = \frac{\sum X_i}{N}$,

Standard Deviation $(\sigma_n) = \sqrt{\frac{\sum (X_i - \bar{X})^2}{N-1}}$,

Coefficient of Variation $= \frac{\sigma_n}{\bar{X}} = \frac{S.D}{Mean}$,

Return Period (Chow 1964): Return period or recurrence interval was calculated by Weibull's plotting position method (Chow 1964).

Return Period (in years) $T = \frac{N+1}{R}$. (1)

Where, N = Total numbers of years of records and R = Rank of the observed rainfall which
Are arranged in descending order.

Ven Te Chow method (Chow, 1964)

The Expected rainfall of the variate X is calculated by the equation.

$X_T = A + BZ$ Where A and B are constant and determined by the equations:

$$A = \left[\sum \frac{X_i}{N}\right] - \left[B \sum \frac{Z_i}{N}\right] \text{ and } B = \frac{\sum z_i x_i - \sum z_i \sum \frac{z_i}{N}}{\sum z_i^2 - \frac{\sum z_i^2}{N}}$$

Description of various probability distribution functions

Distribution	Probability density function	Range	Equation for the parameters in terms of the simple moment
Gumbel	$f(x) = \frac{1}{\alpha} \exp\left[-\frac{x-\mu}{\alpha} - exp\left(-\frac{x-\mu}{\alpha}\right)\right]$	$-\infty < x < \infty$	$\mu = \bar{x} - 0.5772\alpha$, $\alpha = \frac{S_x\sqrt{6}}{\pi}$
Log -Pearson type-III	$f(x) = \frac{1}{a_{y\Gamma(b)}} \left(\frac{y-c}{a}\right) e^{-\frac{1}{2}\left(\frac{y-c}{a}\right)}$	$0 < x < \infty$	$\mu = \bar{x}, \sigma = S_x$
Log- Normal	$f(x) = \frac{1}{x\sigma_{\sqrt{2\pi}}} e^{-\frac{1}{2}\left(\frac{y-\mu_y}{\sigma_y}\right)^2}$ where $y = logx$	$x > 0$	$\mu_y = \bar{y}, \sigma_y = S_y$

Goodness to fit: Integral square error (ISE): The integral square error (ISE) are used to test the goodness of fit the observed and expected rainfall by the formula:

$$ISE = \frac{\left[\sum_{i=1}^{m} (R_{Ei} - R_{Oi})^2\right]^{\frac{1}{2}}}{\sum_{i=1}^{m} R_{Oi}},$$

Where R_{Oi} and R_{Ei} are observed rainfall and expected rainfall respectively. The value of expected rainfall can be given in the table 1 and table 2

3. Result and Discussion

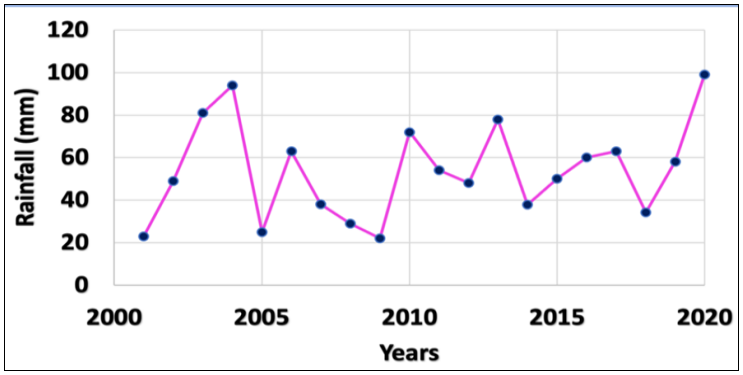

Fig 1: Annual maximum rainfall of Meerut City from 2001-2020.

India received the maximum rainfall by southwest monsoon. It brings approximately 75% rainfall of total annual rainfall in India. The southwest monsoon is the main rainy season in India. It comes from end June to September. The Meerut City received the highest rainfall 99.1mm in 2020 and lowest rainfall 22 mm in the year of 2009. The rainfall data 2004-2020 fluctuates year to year significantly increasing or decreasing long term trend. (Fig.1.)

Table 1: Estimation of One- day annual maximum rainfall of Meerut City from 2001-2020

Probability (%)	Return Period(T) Years	Observed rainfall	Gumbel	VT Chow	Log Pearson Type-III	Log Normal
4.76	21	99.1	83.275	134.967	80.723	77.803
9.52	10.50	94	78.780	111.112	74.644	77.268
14.29	7.00	81	70.961	96.772	70.794	73.113
19.05	5.25	77.9	64.824	86.300	65.917	70.794
23.81	4.20	72	62.115	77.926	63.973	69.502
28.57	3.50	63	55.445	70.855	54.827	57.676
33.33	3.00	63	53.413	64.663	53.703	54.827
38.10	2.63	60	51.340	59.089	52.119	51.880
42.86	2.33	58	49.432	53.965	48.752	46.665
47.62	2.10	54	47.646	49.166	48.611	44.771
52.38	1.91	50	43.993	44.601	48.528	41.304
57.14	1.75	49	42.167	40.193	48.083	39.994
61.90	1.62	48	40.381	35.871	45.919	38.106
66.67	1.50	38	38.575	31.569	42.756	37.325
71.43	1.40	37.9	36.666	27.209	39.627	35.974
76.19	1.31	34.3	32.726	22.698	33.573	33.265
80.95	1.24	29	28.211	17.899	30.199	31.117
85.71	1.17	25	25.502	12.588	28.84	27.352
90.48	1.11	23	22.218	6.304	19.86	25.409
95.24	1.05	22	17.600	-2.274	17.947	22.751

Table 2: Goodness of fit using Integral Square Error (ISE) for one day annual maximum rainfall data of Meerut City

Return period(T) Years	Probability	Observed Rainfall (Ro)mm	Expected rainfall(Re), mm				ISE $= \frac{[\sum_{i=1}^{m}(R_{Ei}-R_{Oi})^2]^{1/2}}{\sum_{i=1}^{m} R_{Oi}}$			
			Gumbel	VenTe Chow	Log Pearson type-III	Log Normal	Gumbel	VenTe Chow	Log Pearson type-III	Log Normal
21	4.76	99.1	83.275	134.967	80.723	77.803	0.0341	0.0566	0.0351	0.0359
10.50	9.52	94	78.780	111.112	74.644	77.268				
7.00	14.29	81	70.961	96.772	70.794	73.113				
5.25	19.05	77.9	64.824	86.300	65.917	70.794				
4.20	23.81	72	62.115	77.926	63.973	69.502				
3.50	28.57	63	55.445	70.855	54.827	57.676				
3.00	33.33	63	53.413	64.663	53.703	54.827				
2.63	38.10	60	51.340	59.089	52.119	51.880				
2.33	42.86	58	49.432	53.965	48.752	46.665				
2.10	47.62	54	47.646	49.166	48.611	44.771				
1.91	52.38	50	43.993	44.601	48.528	41.304				
1.75	57.14	49	42.167	40.193	48.083	39.994				
1.62	61.90	48	40.381	35.871	45.919	38.106				
1.50	66.67	38	38.575	31.569	42.756	37.325				
1.40	71.43	37.9	36.666	27.209	39.627	35.974				
1.31	76.19	34.3	32.726	22.698	33.573	33.265				

1.24	80.95	29	28.211	17.899	30.199	31.117				
1.17	85.71	25	25.502	12.588	28.84	27.352				
1.11	90.48	23	22.218	6.304	19.86	25.409				
1.05	95.24	22	17.600	-2.274	17.947	22.751				

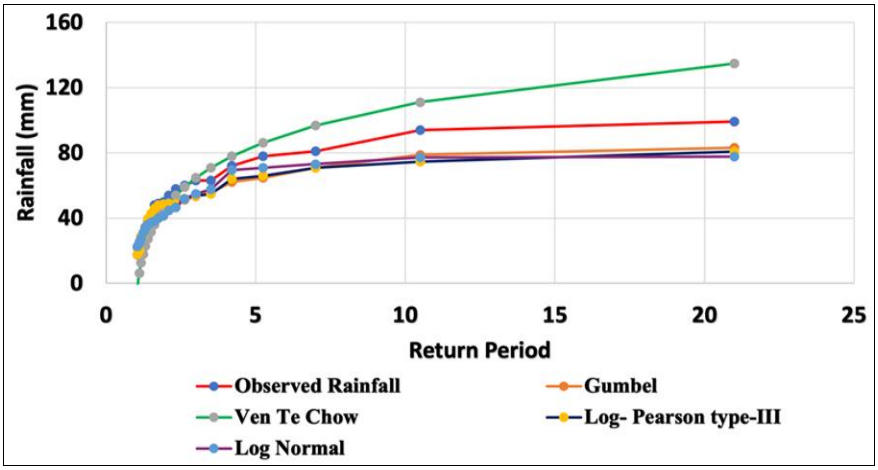

Fig 2: Graph b/w Observed rainfall and distributions for Meerut City 2001-2020.

The probability distributions viz Gumbel, Ven Te Chow, Log Pearson type-III and Log-Normal are used to analyze the one-day annual maximum rainfall (Tab.1 and Fig. 2). It was estimated that the Ven Te Chow was very close to the observed maximum rainfall. The result was drawn by comparing the mean the value of Integral Square Error (ISE) method (Tab. 2).

The average value of Integral Square Error for the statistical distributions of Gumbel, Ven Te Chow, Log-Pearson type-III and Log- Normal were found to be 0.0341, 0.0566, 0.0351 and 0.0359 respectively.

Hence, an important result of the above discussion was extracted that Gumbel was the best fit for the prediction of One-day annual maximum rainfall and Log- Pearson type-III distribution was found the second best fit.

4. Concluding Remarks

This study analyzed 20 years of annual rainfall data of Meerut city from the India Meteorological Department (IMD) Pune, spanning from 2001 to 2020. The goal was to identify the most suitable statistical distribution for predicting for one-day annual maximum rainfall for different return periods. The distributions tested were Gumbel, Ven Te Chow, Log Pearson type-III, and Log Normal.

The results suggested that the Gumbel distribution is most suitable for predicting for one- day annual maximum rainfall. This information is valuable for policy planning and decision-making at the district level, helping authorities make informed decisions regarding water management, infrastructure development, and disaster preparedness based on reliable rainfall predictions

4.1 Acknowledgements

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