



Probability Analysis of Rainfall at Raichur

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ABSTRACT

A detailed statistical analysis of one day maximum, weekly maximum, monthly maximum, seasonal and annual rainfall for Raichur was carried out using 34 years (1977-2010) daily rainfall data collected from Agro meteorological observatory of UAS, Raichur. The 34 years average rainfall of the area is found to be 690.36 mm. For forecasting the one day maximum rainfall Pearson type III distribution and maximum weekly rainfall Normal distribution functions were best fitted. Log-Pearson type III probability distribution was best fitted for maximum monthly and seasonal rainfall and also normally fitted to annual rainfall.

Key words : one day, weekly, monthly, seasonal, annual rainfall and D-Index

Probability analysis can be used for prediction of occurrence of future events from available records of rainfall with the help of statistical methods. Based on theoretical probability distributions, it would be possible to forecast the rainfall of various magnitudes of different return periods. Several distributions have been used for hydrological data analysis as given by Chow (1951) by various investigations.

Agriculture is one of the most vulnerable to climate variability and increased frequency of extreme events (Anju, 2007). This is because crop productivity in many environments (particularly in the tropical regions with low levels of crop management technology) is highly dependent on weather and climate (Challinor et al., 2004). Most of the world's food is produced under rain-fed systems where climate variability and change play an important role in determining productivity (Slingo et al., 2005). The consequences of climate variability and change affect the poor in developing countries than for those living in more prosperous nations (USAID, 2007). Given that both climate variability and change interact, good risk managers should begin to consider both climatic elements in operational and strategic farm planning (Meinke and Stone, 2005).

Rainfall is one of the most important natural resource input to crop production in the tropical region. Out of 189.54 million ha (1996- 97) gross cropped area (including area sown more than once) of the country, 61.3% (116.26 million ha) falls under rainfed farming. In India, the gross irrigated area has been rapidly increasing from 28 million ha in 1960-61 to 72.8 million ha in 1997-98. Despite this

progress, marginal and small farmers constituting 80% of agricultural income group, still depend on rainfed farming. The early or delay in onset of monsoon, early or late withdrawal of monsoon, breaks in monsoon period, unusual heavy or no rainfall during the critical phenol-phase of crops may disturb the normal crop growth and development. To exploit the available rainfall effectively, crop planning and management practices must be followed based on the rainfall amount and distribution at a place.

Bhakar et al., (2008) studied a detailed statistical analysis of weekly and monthly rainfall for Kota was carried out using 35 years (1970-2004) daily rainfall data collected from Central Soil and Water Conservation Research Centre, Kota. The variation in weekly and monthly rainfall pattern was found to be more consistent during monsoon season. For forecasting the weekly and monthly rainfall Weibull's method, Normal, Log-normal and Gamma probability distribution functions were fitted. Calculated Chi-square values were compared with tabular values at 5 per cent level of significance. Using Weibull's (extreme value type III) method weekly rainfall was predicted at various probability levels. Gumbel distribution was found to be fitted well for prediction of weekly and monthly maximum rainfall.

MATERIAL AND METHODS

The daily rainfall data were collected from the Agro-meteorological observatory, UAS, Raichur. The area comes under the northeast dry agro climatic zone Karnataka state, and is situated at 15° 33'-16° 34' North latitudes and 76° 14'- 77° 36' East

longitudes and at an altitude of 256.9 m above mean sea level. The daily rainfall data for a period of 34 years (1977-2010) were converted into one day, weekly, monthly, seasonal and annual rainfall.

Theoretical consideration of probability distributions

The theory of different probability distributions, are given as under. A computer Software Package VTFIT was used to fit the probability distributions.

Probability distributions

One of the important problems in hydrology deals with interpreting a past record of rainfall events, in terms of future probabilities of occurrences. There are many probability distributions that have been found to be useful for hydrologic frequency analysis. These can be summarized as below.

a) Normal distribution: This is a symmetrical, bell shaped, continuous distribution, theoretically representing the distribution of accidental errors about their mean, or the so called law of errors. The probability density function is expressed as

$$P(X) = \frac{1}{\sigma \sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

Where, X= variable; μ = mean value of variable; and σ = the standard deviation.

In this distribution mean, mode and median are same. The total area under distribution is equal to unity.

b) Log normal distribution: This is a transformed normal distribution in which the variable is replaced by its logarithmic value. Its probability density function is

$$P(X) = \frac{1}{X \sqrt{2\pi\sigma^2}} e^{-\frac{(\ln x - \mu)^2}{2\sigma^2}}$$

Where, X = a variable; μ = mean; and σ = standard deviation. This is a skewed distribution of unlimited range in both directions.

c) Exponential distribution: The exponential distribution occurs naturally when describing the lengths of the inter-arrival times in a homogeneous Poisson process. Its probability density function is

$$P(X) = \frac{1}{\sigma} e^{-(x-\mu)/\sigma}$$

Where, X= variable; μ = mean value of variable; and σ = standard deviation.

d) Log pearson type III: The general and basic equation defined the probability density of a Pearson distribution is described below

$$P(X) = \frac{e^{-\frac{y}{\beta}} X^{\beta-1}}{|\beta| \Gamma(\alpha)} \left[\frac{\ln X - \gamma}{\beta} \right]^{\alpha-1}$$

Where, X = variable; α = Shape parameter; β = Scale parameter; and γ = Location parameter.

e) Pearson type III distribution: It states as follows

$$P(X) = \frac{\beta^{-\alpha} (X - \gamma)^{(\alpha-1)} e^{-\frac{(x-\gamma)}{\beta}}}{\Gamma(\alpha)}$$

Where, X = variable; α = Shape parameter; β = Scale parameter; and γ = Location parameter.

f) Gumbel (maxima) distribution: This distribution results from any initial distribution of exponential type, which converts to an exponential function, as x increases. The examples of such initial distributions are normal, chi-square and log normal distributions. The probability density function of type I distribution is

$$P(X) = \frac{e^{-(x-\gamma)/\beta} e^{-e^{-(x-\gamma)/\beta}}}{\beta}$$

Where, X = variable; α = Shape parameter; β = Scale parameter; and γ = Location parameter.

g) Gumbel (minima) distribution: This distribution results from any initial distribution of exponential type, which converts to an exponential function, as x increases. The examples of such initial distributions are normal, chi-square and log normal distributions. The probability density function of type I distribution is

$$P(X) = \frac{e^{-(y-x)/\beta} e^{-e^{-(y-x)/\beta}}}{\beta}$$

Table 1. Probability analysis of maximum one day rainfall

Probability of exceedance (%)	Observed rainfall (mm)	Estimated Rainfall (mm) at different distributions					
		Normal	Log normal	Log pearson type III	Pearson type III	Gumbel (minima)	Gumbel (maxima)
10	176.60	174.70	151.91	158.39	170.99	221.83	144.13
25	111.10	135.34	110.86	107.81	111.02	171.10	110.09
50	66.70	91.60	78.12	73.93	69.46	101.80	80.30
75	49.20	47.86	55.05	53.31	48.82	13.88	56.81
90	42.80	8.50	40.18	41.37	41.74	0.00	39.62
Mean	84.87	88.86	84.10	83.30	83.61	96.65	83.63
SD	50.92	59.77	40.91	43.17	49.25	87.26	37.92
C.V	0.60	0.67	0.49	0.52	0.59	0.90	0.45
D-Index		1.17	0.60	0.43	0.15	2.67	0.78
Fitting Condition		Un Fit	Un Fit	Un Fit	Best Fit	Un Fit	Un Fit

Table 2. Probability analysis of maximum weekly rainfall

Probability of exceedance (%)	Observed rainfall (mm)	Estimated rainfall (mm) at different distributions					
		Normal	Log normal	Log pearson type III	Pearson type III	Gumbel (minima)	Gumbel (maxima)
10	246.00	297.08	250.78	259.13	282.74	481.15	241.00
25	169.85	230.92	188.94	178.93	195.62	430.41	187.83
50	138.40	157.41	137.95	127.60	128.82	361.10	141.28
75	100.30	83.91	100.72	97.75	88.78	273.16	104.59
90	76.50	17.75	75.89	81.26	70.06	172.71	77.74
Mean	142.18	152.81	146.14	143.20	146.16	341.52	146.49
SD	60.06	100.45	63.88	65.86	79.65	110.52	59.24
C.V	0.42	0.66	0.44	0.46	0.54	0.32	0.40
D-Index		0.18	2.47	8.41	0.34	0.25	6.17
Fitting Condition		Best Fit	Un Fit	Un Fit	Un Fit	Fit	Un Fit

Where, X = variable; α = Shape parameter; β = Scale parameter; and γ = Location parameter.

Selection of probability distribution function D-Index

D-Index was adopted for comparison of relative fitness of fit of different distributions. It is one of the non-parametric statistical methods like chi-square test. Hence this relatively simple non-

parametric method (D-index) is adopted for verifying fitness of rainfall probability distributions. The test statistic was calculated from the

$$D\text{-Index} = \frac{\sum_{i=1}^n |X_i \text{ Observed} - X_i \text{ Estimated}|}{X}$$

Where, X = mean of the observed rainfall, mm; and i= Series of rainfall amounts at 10, 25, 50, 60,

Table 3. Probability analysis of maximum monthly rainfall

Probability of exceedance (%)	Observed rainfall (mm)	Estimated rainfall (mm) at different distributions					
		Normal	Log normal	Log pearson type III	Pearson type III	Gumbel (minima)	Gumbel (maxima)
10	328.75	366.17	342.17	348.14	374.26	431.51	368.42
25	270.55	305.30	279.51	267.08	282.00	380.77	289.92
50	211.10	237.67	223.25	210.43	208.94	311.46	221.19
75	180.05	170.03	178.32	175.05	162.66	223.52	167.02
90	145.90	109.16	145.66	154.61	139.08	123.08	127.36
Mean	222.44	233.43	229.01	225.08	225.94	291.88	228.88
SD	66.31	92.43	71.38	71.39	87.60	110.51	87.48
C.V	0.30	0.40	0.31	0.32	0.39	0.38	0.38
D-Index		0.72	0.20	0.18	0.42	2.08	0.46
Fitting Condition		Un Fit	Fit	Best Fit	Un Fit	Un Fit	Un Fit

Table 4. Probability analysis of maximum seasonal rainfall

Probability of exceedance (%)	Observed rainfall (mm)	Estimated rainfall (mm) at different distributions					
		Normal	Log normal	Log pearson type III	Pearson type III	Gumbel (minima)	Gumbel (maxima)
10	727.90	695.12	746.46	711.94	826.74	663.66	699.01
25	606.23	589.87	579.53	590.76	592.85	595.09	563.27
50	452.95	472.93	437.45	460.55	403.28	501.42	444.43
75	364.33	355.98	330.21	342.56	278.43	382.58	350.77
90	230.65	250.73	256.36	251.49	210.96	246.84	282.20
Mean	465.98	465.61	457.27	461.96	443.61	474.96	457.73
SD	177.13	159.81	178.63	167.27	228.46	149.35	151.25
C.V	0.38	0.34	0.39	0.36	0.51	0.31	0.33
D-Index		0.24	0.30	0.18	0.71	0.44	0.33
Fitting Condition		Fit	Fit	Best Fit	Un Fit	Un Fit	Un Fit

75 & 90 per cent probabilities of exceedence.

The D-Index value of less than 0.20 is considered as a best fit, 0.20 to 0.30 is normal fit and above 0.30 will be an unfit distribution as adopted by earlier investigators.

RESULTS AND DISCUSSION

A great deal of hydrological data is required in the design of water-related structures. In most cases, the available amount of data is limited it may

also contain some gaps in the series. When it is decided to carry out a water resources project in a hydrological region, it is first necessary to collect all the information related to the region and then to analyze the collected data. A frequency analysis of the data is the most commonly applied method. Some of the most common and important probability distributions used in the study are the Normal, Log-normal, Exponential, Pearson Type III, Log-Pearson Type III, Gumbel (minima), and Gumbel (maxima).

Table 5. Probability analysis of maximum annual rainfall

Probability of exceedance (%)	Observed rainfall (mm)	Estimated rainfall (mm) at different distributions					
		Normal	Log normal	Log pearson type III	Pearson type III	Gumbel (minima)	Gumbel (maxima)
10	959.95	963.21	975.05	973.18	1127.48	924.56	967.98
25	887.15	833.95	809.83	808.80	812.05	840.36	801.29
50	639.35	690.34	658.87	658.83	580.51	725.33	655.35
75	528.95	546.73	536.06	536.94	452.29	579.39	540.32
90	421.75	417.48	445.23	446.83	399.54	412.70	456.12
Mean	675.26	681.35	672.46	672.44	648.93	692.84	671.68
SD	208.14	196.26	192.24	190.98	274.71	183.41	185.74
C.V	0.31	0.29	0.29	0.28	0.42	0.26	0.28
D-Index		0.22	0.22	0.22	0.73	0.43	0.24
Fitting Condition		Fit	Fit	Fit	Un Fit	Un Fit	Fit

These distributions are normally used to calculate the annual flows of rivers, hydrological variables such as rainfall, runoff and frequency analysis of floods.

The computation of observed and estimated rainfall at different probabilities of exceedance at one day maximum, maximum weekly, maximum monthly, seasonal and annual rainfall at different distributions namely Normal, Log-normal, Exponential, Pearson Type III, Log-Pearson Type III, Gumbel (minima), and Gumbel (maxima) are described below.

Observed rainfall

In order to assess the relative suitability of distributions, computed and observed values were plotted. The different types of observed rainfall was calculated by Weibull's method at 10, 25, 50, 60, 75 and 90 per cent probabilities of exceedance and presented in Tables 1, 2, 3, 4 and 5. Through this was minimally processed to know the comparative ability of the prediction of various fitted theoretical distributions. This minimally processed observed data by Weibull's method is herein referred as "observed rainfall" only.

One day maximum rainfall

The estimated one day maximum rainfall at different probabilities is presented in Table 1. It is seen from this table that the per cent deviations from the probability distributions are more at 10 and 25 per cent probability of exceedance. Also, D-Index

value was found to be minimum for Pearson type III (0.15). Hence, Pearson type III is considered to be best fitted and all other distributions are unfit for the one day maximum rainfall.

It was found that the maximum one day rainfall occurred highest in the year 2009 i.e. 380 mm and lowest was occurred in the year 1980 i.e. 39.4 mm.

Maximum weekly rainfall

The estimated maximum weekly rainfall at different probabilities is presented in Table 2. It was observed that the percent deviations were identified at more in Log-Pearson type III and Gumbel (maxima) of distribution. Also, the D-Index was found to be minimum in Gaussian (0.18) and Gumbel (minima) (0.25) distributions are considered to be fit for the maximum weekly rainfall and all other distributions are unfit for the maximum weekly rainfall.

It was found that the weekly rainfall occurred highest in the year 2009 i.e. 704.6 mm and lowest was occurred in the year 1984 i.e. 58.4 mm.

Maximum monthly rainfall

The estimated monthly rainfall is furnished in Table 3. It is inferred from the table that the percent deviations were registered maximum (from 0.66 to 100.36) at 25 percent probability of exceedance. Also D-Index was observed to be minimum for Log-Pearson Type III (0.18) is considered to be best fitted

Fig. 1. Observed and estimated one day maximum rainfall

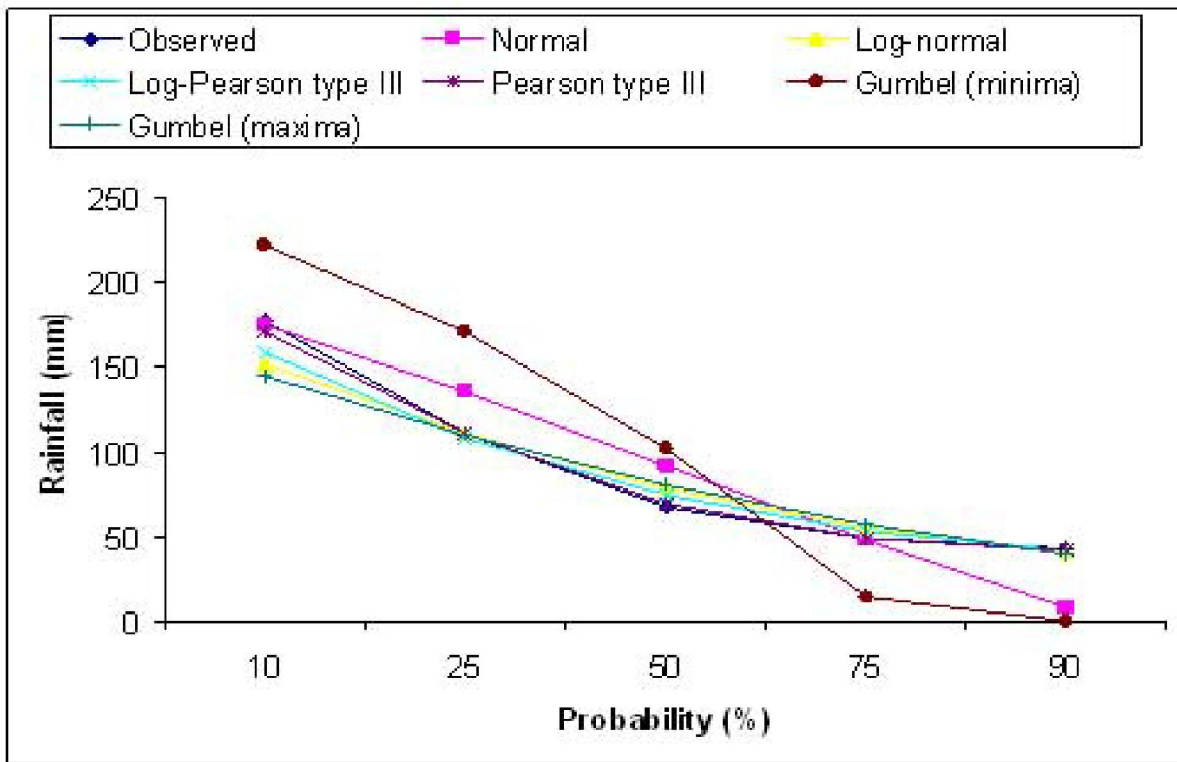


Fig. 2. Observed and estimated maximum weekly rainfall

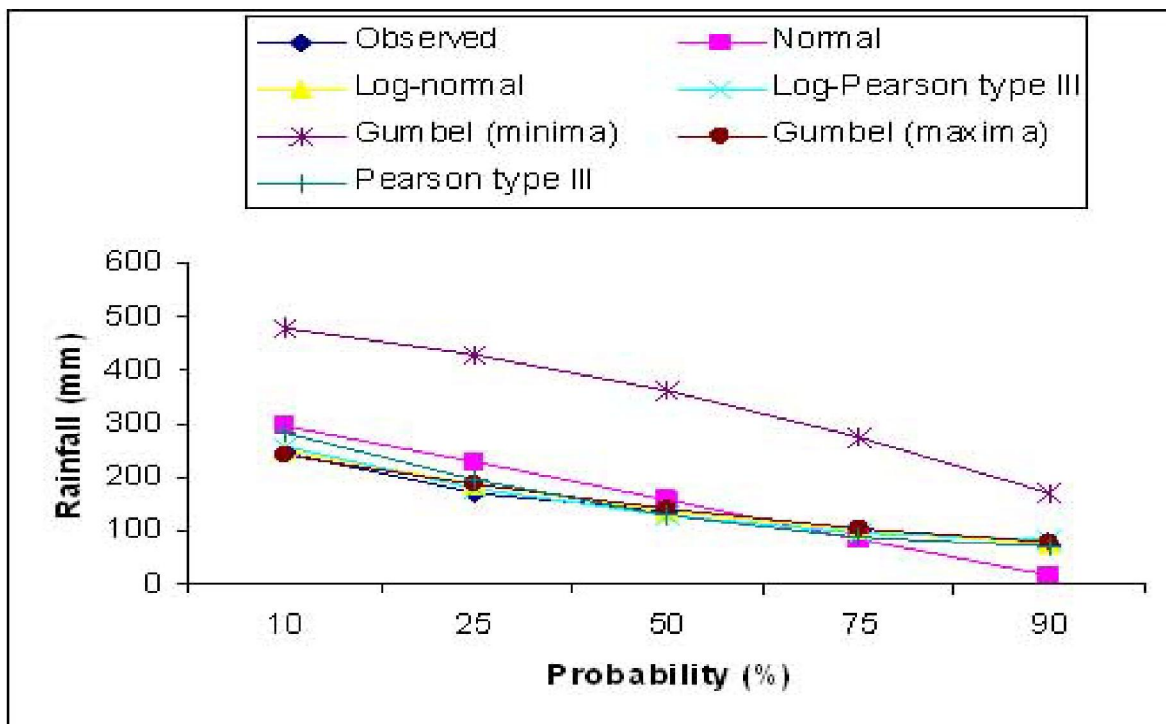


Fig. 3. Observed and estimated maximum monthly rainfall

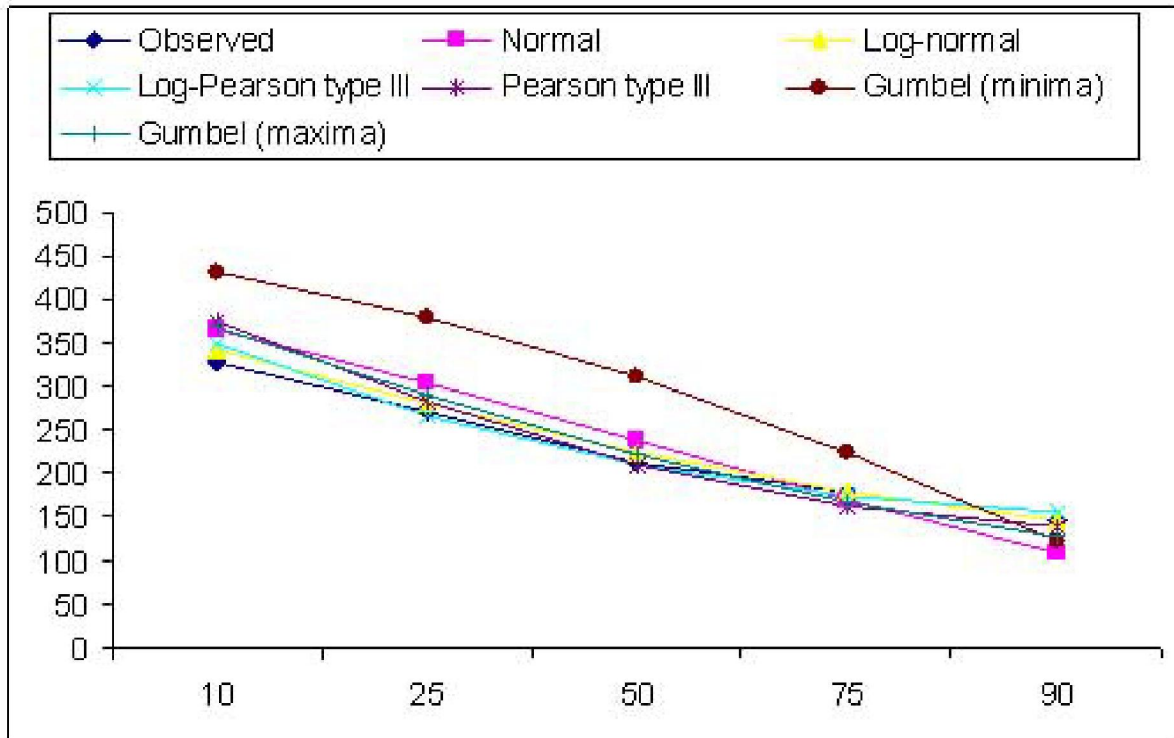


Fig. 4. Observed and estimated seasonal rainfall

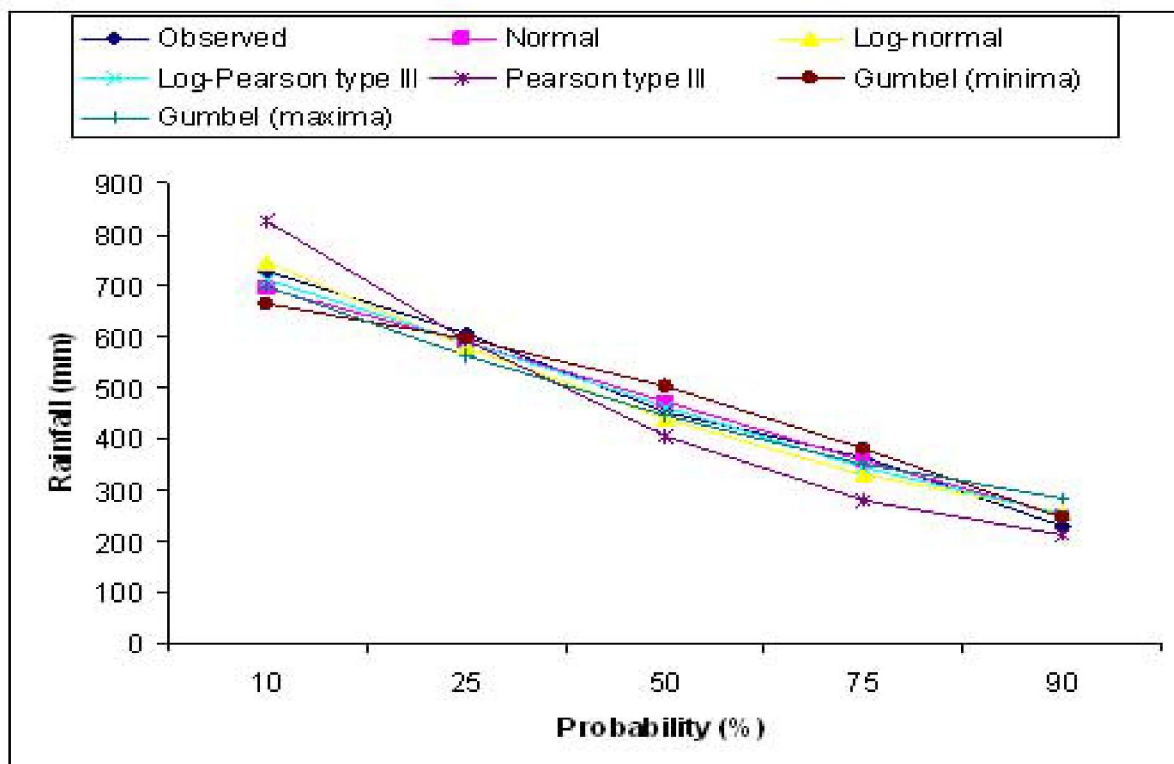
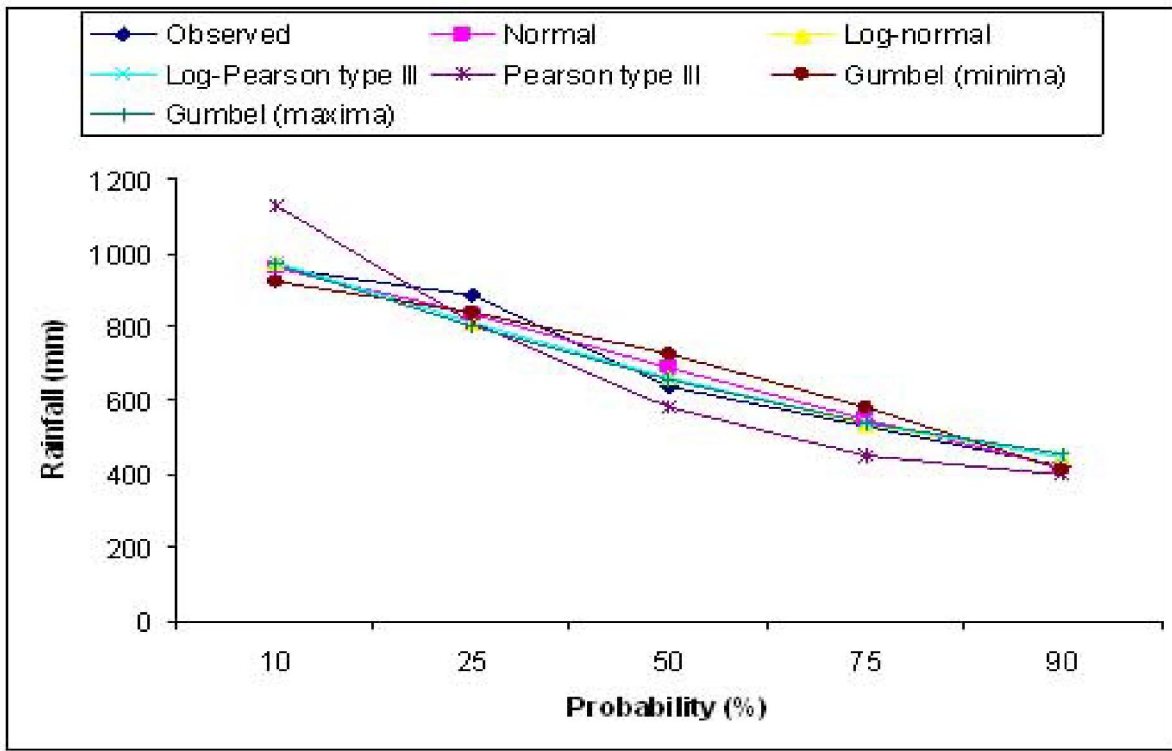


Fig. 5. Observed and estimated annual rainfall



distribution and Log normal distribution (0.20) is considered as normal fit for the maximum monthly rainfall and gave the reliable results for the selected study region. And all other distributions are unfit for the maximum monthly rainfall.

It was found that the maximum monthly rainfall occurred highest in the year 2009 i.e. 704.6 mm and lowest was occurred in the year 2003 i.e. 121.0 mm.

Seasonal rainfall

The estimated seasonal rainfall at different probabilities is presented in Table 4. It was observed that the percent deviations were identified at more in Pearson type III in all the percent probability of exceedance except 25 and 90 percent of exceedance. The D-Index was found to be very minimum in Log Pearson type III i.e. 0.18 and it is best fit for the seasonal rainfall and followed by Normal (0.24) and Log-normal (0.30) distributions are normal fit for the seasonal rainfall. The others distributions are unfit for the estimation seasonal rainfall.

It was found that the seasonal rainfall occurred highest in the year 1988 i.e. 869.1 mm and lowest was occurred in the year 1994 i.e. 150.2 mm.

Annual rainfall

The estimated annual rainfall at different probabilities is presented in Table 5. It was observed that the percent deviations were identified at more in all the percent (10, 25, 50, 60 and 75 percent) probability of exceedance of Pearson type III and Gumbel (minima) except 90 percent of exceedance. Also, the D-Index value was found to be very minimum in Normal (0.22), Log-normal (0.22), and Log-Pearson Type III (0.22) followed by Gumbel (maxima) (0.24) and other two distribution are unfit for annual rainfall. From the result it found that normal distribution followed by Log-normal, Log-Pearson type III and Gumbel (maxima) distributions are normal fit for the annual rainfall and these methods are reliable methods for estimation of annual rainfall.

It was found that the annual rainfall occurred highest in the year 2009 i.e. 1263.3 mm and lowest was occurred in the year 1987 i.e. 374.4 mm.

The observed and estimated rainfall data at different percent of probabilities were also drawn graphically for one day maximum rainfall (Fig.1), maximum weekly rainfall, (Fig.2), maximum monthly rainfall (Fig.3) seasonal rainfall (Fig. 4) and annual rainfall (Fig.5) respectively.

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