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Probability Analysis of Rainfall at Semi Arid Area of Chandrabanda, Raichur District, Karnataka

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ABSTRACT

Daily rainfall data were obtained from the rain gauge station of Chandrabanda and were analyzed for fitting one day maximum rainfall, maximum monthly and annual rainfall data, using different distributions like Normal, Log-normal, Gumbel and Log-Pearson III to determine the best fit distribution, which will be very much useful for design of any water harvesting and soil conservation structures. From the rainfall analysis over the study area, the Log-normal (0.16), and Log-Pearson type III (0.17) distributions are identified for the reliable estimation of one day maximum rainfall with minimum D-index. From the result Log-normal (0.21) and Log-Pearson type III (0.26) distributions are identified for the consistent estimation of maximum monthly rainfall with minimum D-index. For annual rainfall estimation all four distributions namely Normal (017), Log-Pearson type III (0.20), Gumbel (0.26) and Log-normal (0.27) distributions are recognized with minimum D-index. However, from the study Log-Pearson type III and Log-normal distributions are the fitting distributions for all one day maximum, maximum monthly and annual rainfall analysis for the study area.

Key words : D-index; Gumbel; Log-normal; Log-Pearson type III; and Normal.

Amount of rainfall received over an area is an important factor in assessing the amount of water available to meet the various demands of agriculture, industry, and other human activities. Therefore, the study of the distribution of rainfall in time and space is very important for the welfare of the national economy. Precipitation is a key component of the hydrological cycle and one of the most important parameters for various natural and socio-economic systems: Water resources management, agriculture and forestry, tourism, flood protection, to name just a few (Schmidli, 2005). The study of consequences of global climate change on these systems requires scenarios of future precipitation change as input to hydrologic cycle. Hydrological and meteorological data show no random behavior. Then they can be analyzing by some statistical methods based on frequency analyses of precipitation and flood data. Therefore, statistical distributions can be employed for the studies such as the design of water structure, the management of water resource and watershed, and the determination of effective factors about hydrologic cycle. However, it is necessary to determine the best-fitted distribution to studied data. The primary aim of frequency analysis is to relate the magnitude of extreme events to their frequency of occurrence using the probability of distributions (Chow et al., 1988). The aim of this study is to determine suitable probability of distribution models for one day maximum, maximum weekly, maximum monthly, seasonal and annual precipitation data in study area. Six well-known probable distributing models including normal, log normal, Pearson type III, log Pearson type III, Gumbel (minima) and Gumbel (maxima) with moment and maximum likelihood parameters which are tested to determine the best fitted distributions as well as precipitation in different return periods.

Probability distributions are widely used in understanding the rainfall pattern and computation of probabilities (Abdullah and Al-Mazroui, 1998) and it is believed that events follow particular types of distributions (Tilahun, 2006). The normal distribution is one of the most important and widely used in rainfall analysis (Kwaku and Duke, 2007). Despite the wide applicability of the normal distribution there remain many instances when observed distributions are neither normal nor symmetrical. It has been observed that rainfall is not necessarily normally distributed (Stephens, 1974) except in wet regions (Edwards et al., 1983). Jackson (1977) has emphasized that annual rainfall distributions are markedly skew in semi-arid areas and the assumption of normal frequency distribution for such areas is inappropriate. Research elsewhere has shown that rainfall can also be described by other distributions, e.g. Gamma distribution (Abdullah and Almazrovi, 1998 the log-Pearson Type III distribution

Table 1. Probability analysis of maximum one day maximum rainfall.

Probability of Exceedence (%)	Observed Rainfall (mm)	Estimated Rainfall(mm)			
		Normal	Log-normal	Gumbel	Log-Pearson type III
25	97.23	96.07 (1.16)	91.02 (6.21)	104.52 (7.29)	90.63 (6.6)
50	67.00	75.45 (8.45)	69.88 (2.88)	78.51 (11.51)	69.55 (2.55)
75	55.15	54.83 (0.32)	53.65 (1.5)	45.51 (9.64)	53.61 (1.54)
90	42.20	36.28 (5.92)	42.29 (0.09)	7.81 (34.39)	42.58 (0.38)
Mean	65.40	65.66	64.21	59.09	64.09
SD	23.52	25.83	21.16	41.85	20.87
CV	0.36	0.39	0.33	0.71	0.33
D-Index		0.24	0.16	0.96	0.17
Fitting Condition		Normal fit	Best fit	Un fit	Best Fit

Note: The parenthesis represents the deviation of observed and estimated rainfall

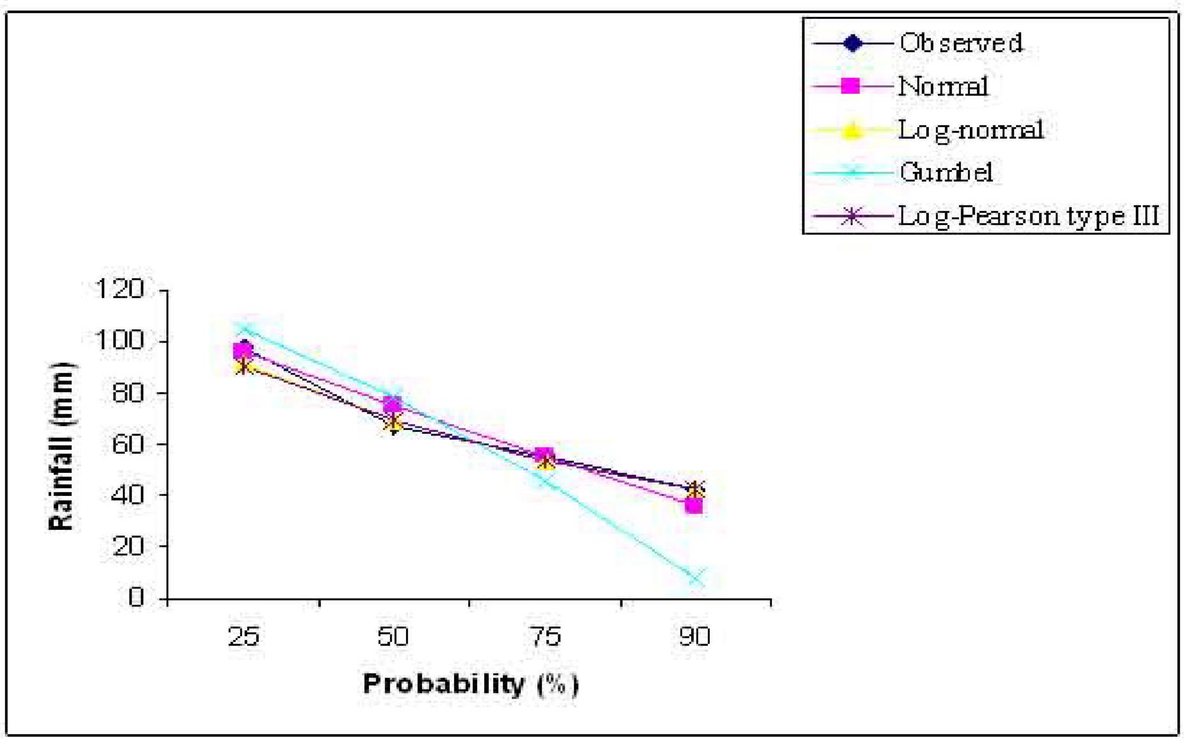

Fig. 1 Observed and estimated one day maximum rainfall

Table 2: Probability analysis of maximum monthly rainfall

Probability of Exceedence (%)	Observed Rainfall (mm)	Estimated Rainfall(mm)			
		Normal	Log-normal	Gumbel	Log-Pearson type III
25	257.63	293.14 (35.51)	266.11 (8.48)	440.02 (182.57)	256.42 (1.21)
50	199.80	219.11 (19.31)	199.41 (0.39)	370.76 (170.96)	191.00 (8.80)
75	171.33	145.06 (26.27)	149.41 (21.92)	282.88 (111.55)	147.95 (23.38)
90	106.95	78.42 (28.53)	115.24 (8.29)	182.51 (75.56)	121.34 (14.39)
Mean	183.93	183.93	137.54	319.04	179.18
SD	62.63	92.75	65.56	111.44	58.95
CV	0.34	0.50	0.36	0.35	0.33
D-Index		0.60	0.21	2.94	0.26
Fitting Condition		Un fit	Normal fit	Un fit	Normal fit

Note: The parenthesis represents the deviation of observed and estimated rainfall

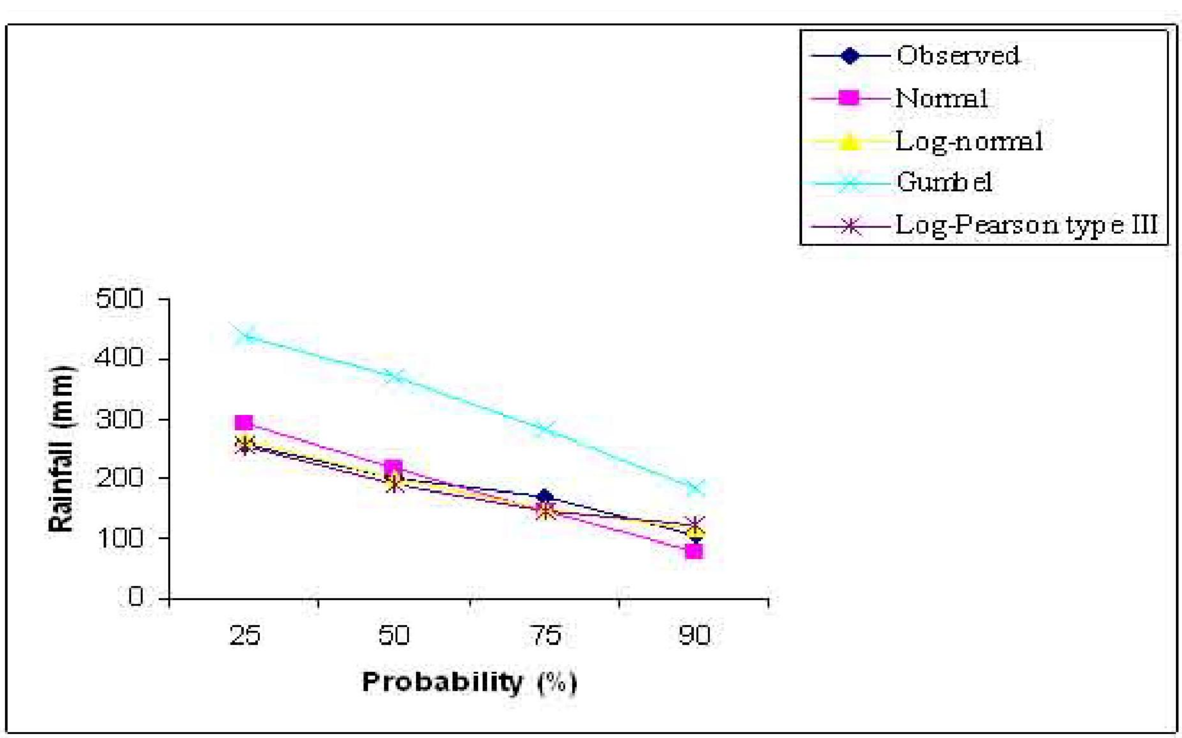

Fig. 2 Observed and estimated maximum monthly rainfall

Table 3. Probability analysis of annual rainfall

Probability of Exceedence (%)	Observed Rainfall (mm)	Estimated Rainfall(mm)			
		Normal	Log-normal	Gumbel	Log-Pearson type III
25	753.28	798.17 (44.89)	785.21 (31.93)	805.68 (52.40)	795.19 (41.91)
50	621.00	629.86 (8.86)	575.27 (45.73)	670.87 (49.87)	606.74 (14.26)
75	482.70	461.55 (21.15)	421.47 (61.23)	499.83 (17.13)	441.01 (41.69)
90	326.20	310.07 (16.13)	318.54 (7.66)	304.47 (21.73)	316.72 (9.48)
Mean	545.80	549.91	525.12	570.21	539.92
SD	183.40	210.84	202.96	216.91	207.55
CV	0.34	0.38	0.39	0.38	0.38
D-Index		0.17	0.27	0.26	0.20
Fitting Condition		Best fit	Normal fit	Normal fit	Normal fit

Note: The parenthesis represents the deviation of observed and estimated rainfall

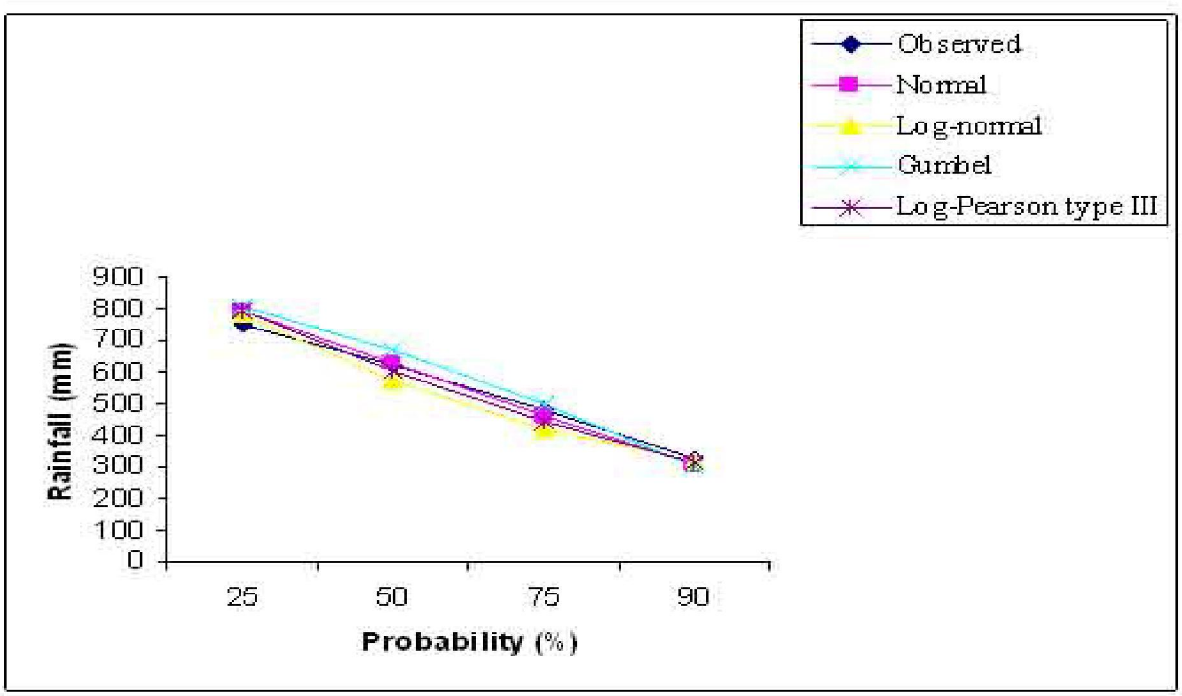

Fig. 3 Observed and estimated annual rainfall

(Chin-Yu Lee, 2005), and the Weibull and Gumbel distributions (Tilahun, 2006).

MATERIAL AND METHODS

The study area is located at 16^0 14^{1}N latitude and 77^0 26^{1}E longitude, 389.5 m above mean sea level. The rainfall data of 34 years from 1975 to 2008 were used for annual one day maximum rainfall, maximum monthly rainfall and annual rainfall. The daily rainfall data were collected from the meteorological observatory of Chandrabanda, Raichur.

The rainfall analysis was done by fitting different theoretical distributions viz., Normal, Log-normal, Gumbel and Log-Pearson type III distributions. For the analysis of the daily rainfall, data was chosen from maximum one day annual rainfall for thirty four years. June to September months for every year was considered for one day maximum, monthly data collection. Similarly the annual rainfall for every year was collected during October to December. The rainfall amounts associated with 25, 50, 75 and 90 percent probability of exceedence were estimated by using standard methods of selected distribution Normal, Log-normal, Gumbel and Log-Pearson type III. The observed rainfall was calculated by Interpolation method at 25, 50, 75 and 90 percent probabilities of exceedence. The different types of rainfall were fitted by the selected probability distribution, which are given below. The fitting of rainfall at different probability distribution will be identified based on observed and estimated rainfall with reference to minimum D-Index.

D-Index

D-Index was adopted for comparison of relative fitness of fit of different distributions and is states that.

$$\text{D-index} = \sum_{i=1}^{4} \frac{|xi \text{ Observed} - xi \text{ Estimated}|}{\bar{x}}$$

$\bar{X}$ = mean of the observed rainfall, mm

i = Series of rainfall amounts at 25, 50, 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.

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

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

Where, x = variable; ì = mean value of variable; and ó = 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

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

Where, X = a variable; ì = mean; and

ó = standard deviation. This is a skewed distribution of unlimited range in both directions.

c) Log Pearson type III:

The general and basic equation defined the probability density of a Pearson distribution is described below

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

Where, X = variable; á = Shape parameter; â = Scale parameter; ¥ = gamma operator; and ã = Location parameter.

d) Gumbel:

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; á = Shape parameter; â = Scale parameter; and ã = Location parameter.

RESULTS AND DISCUSSION

Thirty four years (1975–2008) daily rainfall data were obtained from the meteorological observatory of Chandrabanda. The computation of observed and estimated rainfall at different probabilities of exceedence at one day maximum, maximum monthly and annual rainfall at different distributions namely Normal, Log-normal, Gumbel and Log-Pearson type III are described below and also their mean, standard deviation (S.D.) and coefficient of variation (C.V.) for one day maximum, maximum monthly and annual rainfall over the study area, were calculated and are presented in Tables 1, 2 and 3 respectively.

Maximum one day rainfall

The estimated one day maximum rainfall at different probabilities is presented in Table 1. The percentage deviations from the probability distributions are more at 90 per cent probability of exceedence. The numerical value deviation was observed to be high in Gumbel and Normal distributions when compared to all other distributions. Also, D-Index value was found to be minimum for Log-normal distribution (0.16) followed by Log-Pearson type III (0.17) and Normal distribution (0.24). Hence, Log-normal followed by Log-Pearson type III are found to be best fitted and considered reliable methods to estimate the one day maximum rainfall and also Normal distribution is normally fitted for the one day maximum rainfall, this also confirmed with the help of coefficient of variance. The other one distribution i.e. Gumbel distribution is unfit for the one day maximum rainfall.

Maximum monthly rainfall

The estimated monthly rainfall is shown in Table 2. It is inferred from the table that the percentage deviations were registered maximum (from 1.21 to 182.57) at 25 percent probability of exceedence. Gumbel distribution were identified the more numerical deviation when compared to all other distributions. Also D-Index was observed to be minimum for Log-normal distribution (0.21) and Log-Pearson type III distributions (0.27) are considered to be normally fit for the maximum monthly rainfall. For the estimation of maximum monthly rainfall the Log normal distribution is used as reliable method and, Normal and Gumbel distributions are considered unfit for the maximum monthly rainfall for the selected study area.

Annual rainfall

The estimated annual rainfall at different probabilities is presented in Table 3. The percentage deviations were identified at moderate in all the 25, 50, 75 and 90 percent probability of exceedence. The numerical values deviation ranges maximum for Log-normal distribution i.e. from 7.66 to 61.23 and followed by Gumbel (i.e. 17.13 to 52.40), Log-Pearson type III (i.e. 9.48 to 41.91), and Normal (i.e. 8.86 to 44.89) distributions at different probability exceedence. Also, the D-Index was found to be very minimum in Normal (0.17) distribution. From the results, it could be inferred that the Normal distribution is best fitted for annual rainfall to give the reliable estimates in the selected study area and also found that other three distributions namely Log-Pearson Type III, Gumbel and Log-normal distributions are normally fitted for the study area. The observed and estimated rainfall data at different percent of probabilities were also drawn graphically for One day maximum rainfall (Fig. 1), Maximum monthly rainfall (Fig. 2) and Annual rainfall (Fig. 3) respectively. In graphs, the all lines show the observed rainfall and estimated rainfall of different probabilities at different probability of exceedence.

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