Maximum rainfall probability distributions pattern in Haryana – A case study

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Abstract: The present study has been undertaken to fit best probability distribution of rainfall in Ambala District of Haryana State. The analysis showed that the maximum daily rainfall among the years ranged between 41mm (1980) to 307.9mm (2009) indicating a very large variation during the period of study. The mean of maximum daily rainfall of all years annually is 112.13mm. The means of monthly and weekly values ranged from 33.10-88.92mm and 8.77-46.28 mm, respectively. The maximum daily rainfall in a year/monsoon season was 307.9 mm and monthly maximum daily rainfall in monsoon season ranged from 105 -307.9mm. The weekly maximum daily rainfall ranged from 48 mm-307.9 mm. It was also observed that the minimum among the maximum daily rainfall was 41mm for annual, 34mm for season and 0 in all the months and weeks. The maximum value of coefficient of variation was observed in the first week which indicated a large fluctuation in the rainfall data set and minimum value of coefficient of variation 0.464 was observed for the whole year which shows that fluctuation was minimum for the whole year. Generalized extreme value distribution was found to be best fit probability distribution for most of the periods.

Keywords: Goodness-of-fit tests, Maximum rainfall, Probability distributions

INTRODUCTION

It has long been a topic of interest in the fields of climatology to find a probability distribution that provides a good fit to daily rainfall. Several studies have been conducted in India and abroad on rainfall analysis and best fit probability distribution function such as normal, log-normal, gumbel, weibull and Pearson type distribution were identified (Mayooran, and laheetharan, 2014). Rama Rao et al. (1975) analyzed the daily rainfall data collected at Bijapur for the year 1921 to 1970 at Bijapur. K N Krishnamurthy et al. (2015) studied the distribution of rainfall in the Bengaluru Urban District and observed that normal distribution was found to be the best for annual and seasonal months whereas gamma (2P),Weibull (3P) and general extreme distributions were found to be the best fit probability distributions for most of the weekly periods. Duan et al. (1995) suggested that for modeling daily rainfall data, the weibull and to a lesser extent the exponential distribution is suitable. Upadhyaya and Singh (1998) stated that it is possible to predict rainfall more accurately using various probability distributions for certain returns period although the rainfall varies with space, time and have erratic nature. Sen and Eljadid (1999) reported that for monthly rainfall in arid regions, Gamma probability distribution is the best fit. Oguntela (2001) observed that log-Pearson type III distribution is best to describe the stochastic analysis of peak daily rainfall. Tao et al. (2002) recommended generalized extreme value model as the most suitable distribution after a systematic assessment procedure for representing extreme-value process and its relatively simple parameter estimation. Salami (2004) studied the meteorological data for Texas and found that Gumbel distribution fits adequately for both evaporation and temperature data, while for precipitation data log-Pearson type III distribution confirms to be more accurate. Takara et al. (2013) analyzed the extreme events and revealed that hydrological extremes sometimes do not fit well to the theoretical extreme-value distribution such as the Bumbel and generalized extreme value distributions. Lee (2005) indicated that log-Pearson type III distribution fits for 50% of total station number for the rainfall distribution characteristics of Chian Nan plain area. Bhakar et al. (2006) observed the frequency analysis of consecutive days peaked rainfall at Banswara, Rajasthan, India, and found gamma distribution as the best fit distribution. Kwaku et al. (2007) revealed that the log-normal distribution was the best fit probability distribution for one to five consecutive days’ maximum rainfall for Accra, Ghana. Hanson et al. (2008) indicated that Pearson type III distribution fits the full record of daily precipitation data and Kappa distribution describes best the observed distribution of wet-day daily rainfall. Olofintoye et al. (2009) examined that
The Anderson–Smirnov test and Anderson–Darling test were used
earlier to test the goodness of fit of a sample from a hypothesized distribution.

**MATERIALS AND METHODS**

The present study is based on time series data of maximum daily rainfall in a year, season, month and week. The maximum daily, weekly, monthly, seasonal and annual rainfall data of 47 years (1966 to 2013) were collected from the India Meteorological Department. Various probability distributions namely normal, lognormal (2P, 3P), gamma (2P, 3P), generalized gamma (3P, 4P), log-gamma, weibull (2P, 3P), Pearson 5 (2P, 3P), Pearson 6 (3P, 4P), log-Pearson 3, generalized extreme value were fitted and evaluated by using the Komogorov-Smirnov, Anderson-Darling and Chi-square tests. Different steps/methods were used to find out the results.

**Step I: Fitting the probability distribution:** The probability distributions viz. normal, lognormal, gamma, weibull, Pearson, generalized extreme value were identified to evaluate the best fit probability distribution for rainfall pattern. In addition to these different forms of distributions some other distribution were also tried and thus total 16 probability distributions viz. normal, lognormal (2P, 3P), gamma (2P, 3P), generalized gamma (3P, 4P), log-gamma, weibull (2P, 3P), Pearson 5 (2P, 3P), Pearson 6 (3P, 4P), log-Pearson 3, generalized extreme value were applied to find out the best fit probability distribution. The description of various probability distribution functions viz. density function, range and the parameters involved are presented in Table 1.

**Step II: Testing the goodness of fit:** The goodness of fit test measures the compatibility of random sample with the theoretical probability distribution. The goodness of fit tests was applied for testing the following null hypothesis:

- **H₀:** The maximum daily rainfall data follow the specified distribution.
- **H₁:** The maximum daily rainfall data does not follow the specified distribution.

The following goodness of fit tests viz. Kolmogorov-Smirnov test and Anderson-Darling test were used along with the chi-square test at α(0.01) level of significance for the selection of the best fit Probability distribution.

(i) **Kolmogorov-smirnov Test:** The Kolmogorov-Smirnov statistic (D) is defined as the largest vertical difference between the theoretical and the empirical cumulative distribution function (ECDF):

\[
D = \max \left| F(x_i) - \frac{i - 0.5}{n} \right|
\]

Where \( x_i \) = random sample, \( i = 1, 2 \ldots n \).

(ii) **Anderson-darling test:** The Anderson-Darling statistic (A²) is defined as

\[
A^2 = \frac{1}{n} \sum_{i=1}^{n} D_i^2
\]

It is a test to compare the fit of an observed cumulative distribution function to an expected cumulative distribution function. This test gives more weight to the tails than the Kolmogorov-Smirnov test.

(iii) **Chi-squared test:** \( \chi^2 \) is the Chi-Squared statistic is defined as

\[
\chi^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i}
\]

Where \( O_i \) = observed frequency \( E_i \) = expected frequency \( i \) = number of observations (1, 2, ......., k)

This test is for continuous sample data only and is used to determine if a sample comes from a population with a specific distribution.

**Step III: Identification of best fit probability distribution:** The three goodness of fit tests mentioned above were computed to the maximum rainfall data treating different data set. The test statistic of each test were computed and tested at (α=0.01) level of significance. Accordingly, the ranking of different probability distributions were marked from 1 to 16 based on minimum test statistic value. The distribution holding the first rank was selected for all the three tests independently. The assessments of all the probability distribution were made on the basis of total test score obtained by combining the entire three tests. Maximum score 16 was awarded to rank first probability distribution based on the test statistic and further less scores were awarded to the distribution having rank more than 1, i.e. 2 to 16. Thus the total score of the entire three tests were summarized to identify the best fit distribution on the bases of highest score obtained. The probability distribution having the maximum score was included as a fourth probability distribution in addition to three probability distributions which were previously identified.

**RESULTS AND DISCUSSION**

The methodology presented above was applied to the 47 years weather data in which maximum rainfall
Table 1. Description of various probability distribution functions((Mayooran, and laheetharan, 2014).

| Distribution          | Probability function                                                                 | Range            | Parameters                                                                 |
|-----------------------|--------------------------------------------------------------------------------------|------------------|-----------------------------------------------------------------------------|
| Gamma (3P)            | $f(x)= \frac{1}{\beta \sqrt{2 \pi}} e^{-(x-\gamma)^2/2 \beta^2}$                  | $\gamma \leq x < +\infty$ | $\gamma$ = location parameter yields the two parameter Gamma function       |
| Gamma(2P)             | $f(x)= \frac{1}{\beta \Gamma(\alpha)} x^{\alpha-1} e^{-x/\beta}$                   | $\gamma \leq x < +\infty$ | $\gamma$ = location parameter yields the two parameter Gamma function       |
| Generalized extreme   | $f(x)= \frac{1}{\sigma} e^{\left(-\frac{(x-a)^{1/k}}{\sigma}\right)}$               | $\gamma \leq x < +\infty$ | $\gamma$ = location parameter yields the two parameter Gamma function       |
| Generalized Gamma (4P)| $f(x)= \frac{1}{\sigma^k} \frac{1}{\Gamma\left(\frac{k}{\beta}\right)} x^{k-1} e^{-x/\sigma}$ | $\gamma \leq x < +\infty$ | $\gamma$ = location parameter yields the two parameter Gamma function       |
| Generalized Gamma (3P)| $f(x)= \frac{1}{\sigma^k} \frac{1}{\Gamma\left(\frac{k}{\beta}\right)} x^{k-1} e^{-x/\sigma}$ | $\gamma \leq x < +\infty$ | $\gamma$ = location parameter yields the two parameter Gamma function       |
| Log-Gamma             | $f(x)= \frac{1}{\sigma} e^{\left(-\frac{1}{\sigma}(x-\mu) \right)}$                | $0 \leq x < +\infty$ | $\gamma$ = location parameter yields the two parameter Gamma function       |
| Lognormal(3P)         | $f(x)= \frac{1}{\sigma} e^{\left(-\frac{1}{\sigma}(x-\mu) \right)}$                | $0 \leq x < +\infty$ | $\gamma$ = location parameter yields the two parameter Gamma function       |
| Lognormal(2P)         | $f(x)= \frac{1}{\sigma} e^{\left(-\frac{1}{\sigma}(x-\mu) \right)}$                | $0 \leq x < +\infty$ | $\gamma$ = location parameter yields the two parameter Gamma function       |
| Normal                | $f(x)= \frac{1}{\beta} \left(\frac{x-\gamma}{\beta}\right)^{n-1} e^{\left(-\frac{x-\gamma}{\beta}\right)^n}$ | $0 \leq x < +\infty$ | $\gamma$ = location parameter yields the two parameter Gamma function       |
| Pearson 5 (3P)        | $f(x)= \frac{1}{\beta} \left(\frac{x-\gamma}{\beta}\right)^{n-1} e^{\left(-\frac{x-\gamma}{\beta}\right)^n}$ | $0 \leq x < +\infty$ | $\gamma$ = location parameter yields the two parameter Gamma function       |
| Pearson 5 (2P)        | $f(x)= \frac{1}{\beta} \left(\frac{x-\gamma}{\beta}\right)^{n-1} e^{\left(-\frac{x-\gamma}{\beta}\right)^n}$ | $0 \leq x < +\infty$ | $\gamma$ = location parameter yields the two parameter Gamma function       |
| Pearson 6 (4P)        | $f(x)= \frac{1}{\beta \Gamma(\alpha_1, \alpha_2, \delta, \phi, \kappa)}$              | $\gamma \leq x < +\infty$ | $\gamma$ = location parameter yields the three parameter Pearson 6 function |
| Pearson 6 (3P)        | $f(x)= \frac{1}{\beta \Gamma(\alpha_1, \alpha_2, \delta, \phi, \kappa)}$              | $\gamma \leq x < +\infty$ | $\gamma$ = location parameter yields the three parameter Pearson 6 function |
| Weibull (3P)          | $f(x)= \frac{1}{\beta} e^{\left(-\frac{x-\gamma}{\beta}\right)^n}$                  | $0 \leq x < +\infty$ | $\gamma$ = location parameter yields the two parameter Weibull distribution |
| Weibull (2P)          | $f(x)= \frac{1}{\beta} e^{\left(-\frac{x-\gamma}{\beta}\right)^n}$                  | $0 \leq x < +\infty$ | $\gamma$ = location parameter yields the two parameter Weibull distribution |
Table 2. Summary of statistics for maximum daily rainfall from the year 1966 to 2013.

| Study Period | Mean   | SD     | Skewness | C.V.   | Max    | Min   | Quartile Q1 | Quartile Q3 |
|---------------|--------|--------|----------|--------|--------|-------|-------------|-------------|
| Annual        | 1 Jan-31 Dec | 112.13 | 52.056   | 1.7433 | 0.46425 | 307.9 | 41          | 81          | 125         |
| Seasonal      | 1 June-30 Sep | 111.17 | 53.164   | 1.6179 | 0.47823 | 307.9 | 34          | 81          | 113.75      |
| June          | 1 June-30 June | 33.096 | 23.654   | 0.88517| 0.71472 | 105   | 0           | 15.25       | 46.52       |
| July          | 1 July-31 July | 88.919 | 56.083   | 1.3757 | 0.63072 | 307.9 | 0           | 52.75       | 113.75      |
| August        | 1 Aug-31 Aug  | 68.7   | 48.154   | 1.6524 | 0.70093 | 239   | 0           | 40          | 91.25       |
| Sept          | 1 Sep-30 Sep  | 49.879 | 38.037   | 0.49101| 0.76258 | 131.7 | 0           | 21.25       | 80.75       |
| 1 week        | 4 June-10 June | 8.775  | 18.598   | 3.0801 | 2.1195  | 84.7  | 0           | 10          | 26.75       |
| 2 week        | 11 June-17 June | 10.871 | 14.623   | 1.2571 | 1.3452  | 48    | 0           | 0           | 21          |
| 3 week        | 18 June-24 June | 16.338 | 22.953   | 1.791  | 1.4049  | 105   | 0           | 0           | 27.25       |
| 4 week        | 25 June-1 July | 18.929 | 19.869   | 1.614  | 1.0497  | 90    | 0           | 1.25        | 26.75       |
| 5 week        | 2 July-8 July  | 37.394 | 45.211   | 1.6641 | 1.209   | 196.7 | 0           | 3           | 59.725      |
| 6 week        | 9 July-15 July | 32.304 | 25.53    | 0.76314| 0.79031 | 102   | 0           | 12          | 49.5        |
| 7 week        | 16 July-22 July| 38.744 | 44.877   | 1.5457 | 1.1583  | 206.7 | 0           | 2.25        | 66.8        |
| 8 week        | 23 July-29 July| 46.277 | 57.471   | 2.408  | 1.2419  | 307.9 | 0           | 7.075       | 63.25       |
| 9 week        | 30 July-5 Aug  | 40.904 | 43.713   | 2.2876 | 1.0687  | 239   | 0           | 14.2        | 49.3        |
| 10 week       | 6 Aug-12 Aug   | 28.971 | 27.137   | 1.1734 | 0.9367  | 119   | 0           | 5.25        | 42.1        |
| 11 week       | 13 Aug-19 Aug  | 30.756 | 29.809   | 1.2474 | 0.96919 | 121   | 0           | 7.25        | 42.225      |
| 12 week       | 20 Aug-26 Aug  | 24.565 | 33.775   | 1.9586 | 1.3749  | 158   | 0           | 0           | 39.225      |
| 13 week       | 27 Aug-2 Sep   | 26.11  | 38.842   | 3.3275 | 1.4876  | 225   | 0           | 0           | 36.5        |
| 14 week       | 3 Sep-9 Sep    | 23.721 | 31.659   | 1.7436 | 1.3346  | 131.7 | 0           | 0           | 14.5        |
| 15 week       | 10 Sep-16 Sep  | 19.613 | 31.195   | 1.7663 | 1.5906  | 112.1 | 0           | 0           | 23.25       |
| 16 week       | 17 Sep-23 Sep  | 10.838 | 19.033   | 2.2753 | 1.7562  | 81    | 0           | 0           | 12.675      |
| 17 week       | 24 Sep-30 Sep  | 15.785 | 32.009   | 2.3677 | 2.0277  | 125   | 0           | 0           | 20.5        |
Table 3. Study period wise first ranked probability distribution using goodness of fit tests.

| Study Period | Kolmogorov Smirnov Distribution | Statistics | Anderson Darling Distribution | Statistics | Chi-Square Distribution | Statistics |
|--------------|--------------------------------|------------|-------------------------------|------------|-------------------------|------------|
| Annual       | Gen. Extreme                   | .07378     | Gen. Extreme                  | .02035     | Lognormal               | 0.312888   |
| Seasonal     | Gen. Extreme                   | .08439     | Gen. Extreme                  | .32114     | Pearson 6               | .85293     |
| June         | Gen. Extreme                   | .07294     | Gen. Extreme                  | .19153     | Gamma                   | 0.82822     |
| July         | Gen. Gamma                     | .08462     | Gen. Extreme                  | .39106     | Gen. Extreme            | 0.79631     |
| August       | Gen. Extreme                   | .09279     | Gen. Extreme                  | .6191      | Pearson 6               | 4.7585      |
| Sept         | Gen. Extreme                   | .11961     | Gen. Extreme                  | .78035     | Lognormal               | 0.93463     |
| 1 week       | Normal                          | .31853     | Weibull                       | -5.5831    | Normal                  | 14.073      |
| 2 week       | Normal                          | .24847     | Weibull                       | -1.6365    | Normal                  | 8.7168      |
| 3 week       | Normal                          | .2383      | Gamma                         | 1.7723     | Normal                  | 8.8549      |
| 4 week       | Gen. Extreme                   | .12316     | Gen. Extreme                  | 0.9947     | Gen. Extreme            | 2.1798      |
| 5 week       | Gen. Extreme                   | .12583     | Gen. Extreme                  | 0.4454     | Gen. Extreme            | 1.0918      |
| 6 week       | Gen. Extreme                   | .0828      | Gen. Extreme                  | 1.3722     | Pearson 5               | 5.0899      |
| 7 week       | Gen. Extreme                   | .13271     | Gen. Extreme                  | 0.6685     | Pearson 5               | 1.9855      |
| 8 week       | Gen. Extreme                   | .10819     | Gen. Extreme                  | 0.4512     | Gamma (3P)              | 1.3943      |
| 9 week       | Gen. Extreme                   | .08376     | Gen. Extreme                  | .56004     | Gen. Extreme            | 2.4656      |
| 10 week      | Gen. Extreme                   | .09081     | Gen. Extreme                  | .40648     | Gamma(3P)               | 1.3868      |
| 11 week      | Gen. Extreme                   | .08791     | Gen. Extreme                  | 2.2935     | Gen. Extreme            | 8.9913      |
| 12 week      | Gen. Extreme                   | .1665      | Gen. Extreme                  | 1.1948     | Gen. Extreme            | 3.1964      |
| 13 week      | Gen. Extreme                   | .13938     | Gen. Extreme                  | 1.8772     | Gen. Extreme            | 5.7725      |
| 14 week      | Gen. Extreme                   | .1765      | Gen. Extreme                  | 3.1495     | Gen. Extreme            | 8.8568      |
| 15 week      | Gen. Extreme                   | .21102     | Weibull (3P)                  | -8.7009    | Gen. Extreme            | 8.8169      |
| 16 week      | Normal                          | .28458     |                                |            |                        |            |
| 17 week      | Normal                          | .34026     | Weibull (3P)                  | -4.4725    | Normal                  | 15.704      |

(mm) were taken from daily rainfall. The various probability distribution functions are described in Table 1. The annual maximum daily rainfall ranged from 41 to 307.9 mm during the study period and is presented in Fig.1. The data was classified into 23 data sets. These 23 data sets were classified as 1 annual (Jan to Dec.), 1 seasonal (June to Sept.), 4 months of rainy season and 17 weeks (from Standard Meteorological (week no.23 to 39) to study the distribution pattern at different levels. The summary statistics (mean, standard deviation, skewness coefficient, coefficient of variation, maximum and minimum values of daily maximum rainfall) are presented in Table 2. It is observed that mean of maximum daily rainfall of all years annually is 112.13 mm, seasonal mean value is 111.17 mm. The means of monthly and weekly values ranged from 33.10-88.92 mm and 8.77-46.28 mm, respectively. The maximum daily rainfall in a year/monsoon season was 307.9 mm. During different months (i.e. June, July, August & September) of monsoon period, the maximum daily rainfall ranged from 105-307.9 mm. The weekly maximum daily rainfall ranged from 48 mm-

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It was also observed that the minimum among the maximum daily rainfall was 41mm for annual, 34mm for season and 0 in all the months and weeks. The maximum value of coefficient of variation was observed in the first week which indicates a large fluctuation in the rainfall data set and minimum value of coefficient of variation 0.464 was observed for the whole year which shows that fluctuation was minimum for the whole year.

The test statistics $D$, $A^2$ and $\chi^2$ for each data set were computed for sixteen probability distribution and the probability distribution having the first rank along with their test statistic is presented in Table 3. It was observed that Generalized extreme value distribution using Kolmogorov Smirnov test, Generalized Extreme value using Anderson Darling test and Pearson(6) using Chi-square test obtained the first rank for maximum daily monsoon rainfall. Thus the two probability distributions were identified as the best fit based on these three tests independently. The months of July and August on which the monsoon period remained centered are best expressed by generalized extreme distributions were identified as the best fit based on these three tests independently. The months of July and August on which the monsoon period remained centered are best expressed by generalized extreme

| Study Period | Distribution | Parameters |
|--------------|--------------|------------|
| Annual       | 1 Jan-31 Dec | Gen. Extreme Value | k=0.18315 =31.421 =87.11 |
| seasonal     | 1 June-30 Sep| Lognormal (3P)    | $\sigma=0.5113 \mu=4.3917 \gamma=19.897$ |
|              |              | Gen. Extreme Value | $k=0.13518 \sigma=34.398 \beta=86.048$ |
|              |              | Pearson 6 (4P)    | $\alpha=60.716 \beta=9.173 \gamma=19.817$ |
| June         | 1 June-30 June| Gen. Extreme Value | $k=0.0119 \alpha=19.164 \beta=22.257$ |
|              |              | Gamma           | $\alpha=1.9576 \beta=16.906$ |
| July         | 1 July-31 July| Gen. Gamma      | $k=1.0441 \beta=35.373 \alpha=2.7505$ |
|              |              | Gen. Extreme Value | $k=-0.03467 \sigma=44.12 \mu=64.918$ |
| August       | 1 Aug-31 Aug | Gen. Extreme Value | $k=0.09353 \sigma=32.454 \mu=46.678$ |
|              |              | Pearson 6       | $\alpha=2.203 \alpha=8.2807E+7 \beta=2.6904E+9$ |
| Sept         | 1 Sep-30 Sep | Gen. Extreme Value | $k=0.03777 \sigma=32.379 \mu=32.359$ |
|              |              | Lognormal       | $\alpha=0.99988 \mu=3.6612$ |
| 1 week       | 4 June-10 June| Normal          | $\sigma=18.598 \mu=8.775$ |
|              |              | Weibull         | $\alpha=0.24843 \beta=1.1293$ |
| 2 week       | 11 June-17 June| Normal        | $\sigma=14.623 \mu=10.871$ |
|              |              | Weibull         | $\alpha=0.19133 \beta=1.569$ |
| 3 week       | 18 June-24 June| Normal        | $\sigma=22.953 \mu=16.338$ |
|              |              | Gamma           | $\alpha=0.50664 \beta=32.246$ |
| 4 week       | 25 June-1 July| Gen. Extreme Value | $k=0.17691 \beta=12.288 \mu=9.2559$ |
| 5 week       | 2 July-8 July | Gen. Extreme Value | $k=0.32213 \beta=22.151 \mu=14.391$ |
| 6 week       | 9 July-15 July| Gen. Extreme Value | $k=0.02839 \beta=21.199 \mu=20.648$ |
|              |              | Normal          | $\sigma=25.53 \mu=32.304$ |
| 7 week       | 16 July-22 July| Gen. Extreme Value | $k=0.2572 \sigma=24.881 \mu=15.999$ |
| 8 week       | 23 July-29 July| Gen. Extreme Value | $k=0.33074 \sigma=26.308 \mu=18.477$ |
| 9 week       | 30 July-5 Aug | Gen. Extreme Value | $k=0.2447 \sigma=23.375 \mu=20.039$ |
| 10 week      | 6 Aug-12 Aug | Gen. Extreme Value | $k=0.13907 \sigma=18.559 \mu=15.516$ |
| 11 week      | 13 Aug-19 Aug| Gen. Extreme Value | $k=0.17418 \sigma=19.145 \mu=15.759$ |
| 12 week      | 20 Aug-26 Aug| Gen. Extreme Value | $k=0.38348 \sigma=14.332 \mu=7.6545$ |
| 13 week      | 27 Aug-2 Sep | Gen. Extreme Value | $k=0.40048 \sigma=14.187 \mu=8.7415$ |
| 14 week      | 3 Sep-9 Sep | Gen. Extreme Value | $k=0.37874 \sigma=13.692 \mu=7.7287$ |
| 15 week      | 10 Sep-16 Sep| Gen. Extreme Value | $k=0.50757 \sigma=9.7111 \mu=4.3207$ |
| 16 week      | 17 Sep-23 Sep| Gen. Extreme Value | $k=0.57128 \sigma=4.7674 \mu=1.9351$ |
|              |              | Normal          | $\sigma=19.033 \mu=10.838$ |
|              |              | Weibull         | $\alpha=0.22523 \beta=1.4678$ |
| 17 week      | 24 Sep-30 Sep| Normal         | $\sigma=32.009 \mu=15.785$ |
|              |              | Weibull         | $\alpha=0.20662 \beta=1.0945$ |
identify the one more probability distribution in addition to distribution identified earlier for obtaining the best fit probability distribution. This distribution was identified using maximum overall score based on sum of individual point score obtained from three selected goodness of fit tests. The distributions identified which were having highest score are presented in Table 4. The distributions with same highest score were also included in the selected probability distribution. For annual data set Pearson 5 (3P) having highest score of 43 was selected. It was also observed that some of the probability distributions already having the first rank in Table 3 were also having the highest scores and hence three or less distributions were identified. The distributions so identified are listed in Table 5 where the parameters of these identified distributions for each study period are mentioned in Table 4. Weibull (3P) distribution was found to be the best fit among the 11 fitted distributions by the Krishnamurthy et al. (2015). As reported by the Bhim et al. (2012) log-Pearson distribution was found to be the best fit probability distribution. In our study the General extreme value distribution was found to be the best fit probability distribution. The results show that both annual and seasonal maximum daily rainfall was observed to be 307.9 in the current study whereas in case of Krishnamurthy et al. (2015) and Bhim et al. (2015), it was found to be 200 mm and 252.98 mm respectively.

**Conclusion**

Probability distribution of rainfall analysis has always attracted much attention due to erratic behavior over space and time. Thus the identifying the best distribution is of vital importance for better planning and management of the water especially for agrarian state like Haryana where agriculture pattern is intensive. Since India is facing the problem of drought in the year 2002, 2004, 2009, 2014 and 2015. So by studying the distribution of rainfall in the district or village level the water management can be done. In overall General extreme value distribution was found to be the best for annual, seasonal, weekly and monthly followed by

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**Table 5. Score wise best fit probability distribution.**

| Study Period | Distribution with highest Score |
|--------------|---------------------------------|
|              | Distribution | Score |
| Annual       | Gen. Extreme Value | 41 |
|              | Pearson 5      | 43 |
| Seasonal     | Gen. Extreme Value | 45 |
| June         | Gen. Extreme Value | 46 |
|              | Gamma           | 45 |
| July         | Gen. Extreme Value | 43 |
| August       | Gen. Extreme Value | 46 |
| Sept         | Gen. Extreme Value | 40 |
| 1 week       | Normal          | 45 |
| 2 week       | Normal          | 45 |
| 3 week       | Normal          | 46 |
| 4 week       | Gen. Extreme Value | 48 |
| 5 week       | Gen. Extreme Value | 48 |
| 6 week       | Gen. Extreme Value | 46 |
|              | Normal          | 46 |
| 7 week       | Gen. Extreme Value | 44 |
| 8 week       | Gen. Extreme Value | 48 |
| 9 week       | Gen. Extreme Value | 47 |
| 10 week      | Gen. Extreme Value | 48 |
| 11 week      | Gen. Extreme Value | 47 |
| 12 week      | Gen. Extreme Value | 48 |
| 13 week      | Gen. Extreme Value | 48 |
| 14 week      | Gen. Extreme Value | 48 |
| 15 week      | Gen. Extreme Value | 48 |
| 16 week      | Gen. Extreme Value | 45 |
| 17 week      | Normal          | 45 |

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*Fig. 1. Annual maximum rainfall (mm) at Ambala during 1966-2013 (Source: Indian Meteorological Department).*

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Lognormal (3P), Gamma and normal distribution.

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