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Comparative Study of Prediction of Annual Maximum Rainfall By Using three Different Methods in Bijnor District (U.P.)

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Abstract: Efficient utilization of rainfall water may increase the agricultural production many folds. Though the nature of rainfall is erratic and varies with time and space, yet it is possible to predict design rainfall fairly accurately for certain return periods using various probability distribution functions. The annual maximum rainfall at Bijnor District was 1746.472 mm, 1768.998mm, 1383.958mm, 1741mm for predicted annual maximum rainfall and observed annual maximum rainfall respectively. It is clearly indicates the Gumbel distribution was very near to the observed annual maximum rainfall and predicted annual maximum rainfall (mm). Log Normal and Log Pearson type-III distribution was found to be best model for predicted annual maximum rainfall and observed annual maximum rainfall (mm). The coefficient of determination for predicted, annual maximum rainfall was (0.9141, 0.6777, and 0.7343) close to 1 which showed better dependence of predicted annual maximum rainfall on observed annual maximum rainfall the coefficient value of determination tends towards zero.

Keywords: Rainfall, Gumbel distribution, Log Normal, Log Pearson type-III distribution, Coefficient value

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I. Introduction

Agriculture development largely depends upon the management of resources. India receives adequate amount of rainfall annually through the four different types of weather phenomena viz., south-west monsoon (76%). Northeast monsoon (3%), pre monsoon (13%) and post monsoon (10%).The distribution in time and space in erratic and resulting in limitation on the length of crop growing period or the occurrence of floods. In rain fed farming, the crop planning and its success depend upon the amount and distribute of rainfall, rainfall, at 80% probability can safely be taken as dependable rainfall while that of 50% probability levels is the maximum limit for taking risk **(Gupta *et al.* 1975).**

Probability analysis can be used for prediction of occurrence of future events from available records of rainfall with the help of statistical methods **(Kumar and Kumar 1989)**. Based on theoretical probability distributions, it would be possible to forecast the rainfall of various magnitudes of different return periods. Analysis of Predicted annual maximum rainfall and observed annual maxim rainfall probability level is the basic tools for safe and economic planning and design of structural and non- structural measures, small and medium hydraulic structure such as small dams, bridges, culverts, spillways Check Dams, Ponds, Irrigation and drainage works in the watershed. The monsoon, the annual rainfall is highly variable from year to year variability is high in the region of low rainfall. Areas of moderate and low rainfall. Areas of high rainfall area liable to be affected by floods. Areas of moderate and low rainfall are drought prone. Rural India in most several droughts occurred in 1972 and 1987.The droughts of to lesser intensity during 1965, 1968, 1990 and 1995. It is also common to experience 3 to 4 successive drought in some parts of the country or the other but the most chronic state in this respect are Rajasthan, Karnataka, Andhra Pradesh, Maharashtra and Gujarat.**(Ray *et al.*, 1987).**

Efficient utilization of rainfall water may increase the agricultural production many folds. Though the nature of rainfall is erratic and varies with time and space, yet it is possible to predict design rainfall fairly accurately for certain return periods using various probability distribution functions **(Upadhyaya and Singh, 1998).** Frequency analysis of rainfall data has been attempted for different places in Indian **(Prakash and Rao, 1986; Aggrawal *et al.*, 1998, Bhatt *et al.*, 1996; Upadhyaya and Singh, 1998; Mohanty *et al.*, 1999; Rizvi *et al.*, 2001 and Singh 2001).** Frequency analysis of rainfall data is an important tool for solving various water management problems and is used to assess the extent of crop failure due to deficiency or excess of rainfall. Probability analysis of annual maximum daily rainfall data for different return periods has suggested for the design of small and medium hydraulic structure **(Bhatt *et al.*, 1996).**

The economics benefits of more accurate weather forecast are immense. Rainfall modeling and its forecasting is one of the important factors for catchments level water resources management design. The Indian Ocean atmospheric circulations influence more than 1.5 billion people in arid and semiarid Asia. Thus prediction of annual rainfall is essential input parameter for decision supported modeling as well as the hydrological impact assessment studies. Due to climatologically factor and regional conditions there is no general agreement among hydro- meteorologists and researchers about the selection of a probability distribution function to carry out frequency analysis. According to **Kite (1977)** the most important criteria in selection of distribution functions are (i) it should be theoretically based function: and (ii) it should extract the maximum information from the data available. **Chow (1951).**

II. Materials And Methods

The probability analysis of annual maximum rainfall for different probability levels has been suggested for the design of small and medium hydraulic structure. The primary need of water resource development in any area depends on the estimation of rainfall at different probabilities for efficient planning and design of irrigation and drainage system, command area development, soil and water conservation programmers and the optimum utilization of water resources in various agricultural production systems. Most of the watershed planning activities includes the design of water storage structures and erosion control structure and efficient utilization of runoff for irrigation of different crops. Hence the analysis of rainfall at different duration like predicted annual maximum rainfall and predicted rainfall is important for better planning and management of water resources.

The methodology adopted for the probability analysis of rainfall data of 20^{th} years (1990-2009) to predict the annual maximum rainfall for Bijnor District are present in this chapter :

III. Description Of Study Area

3.1.1 Location and topography

The study area of Bijnor district is located in the Northern part of the state $29^0 28^1$ N latitude to $78^0 32^1$ E longitude and shed at the confluence of the Ganga and Ram Ganga Rivers. The Map showing location and boundaries of Bijnor District is figure 3.1

3.1.2 Demography

Bijnor has an area of about 4561 sq. km (1761.01195 sq. miles) and is 245 m above sea level. Bijnor District has a population of 2370268 as per the 2001 census with about 1251936 males and 1118332 females. Languages spoken in and around Bijnor include Hindi, English, Urdu, and some Garhwali and Punjabi.
(Department of Agriculture, Bijnor District).

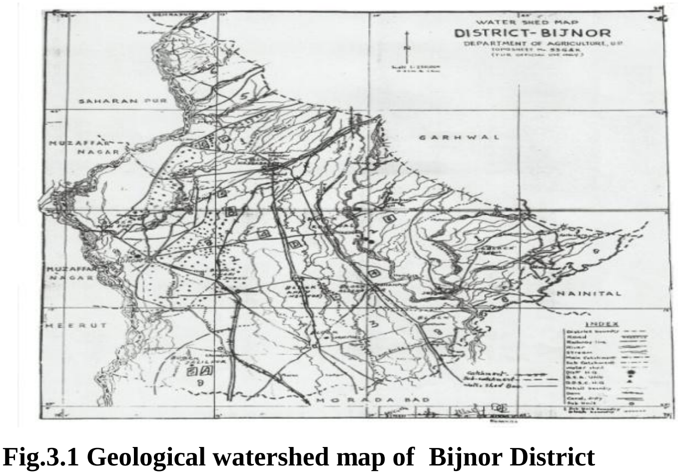

Fig.3.1 Geological watershed map of Bijnor District

3.1.3 Climate

Bijnor District comes under Humid sub – tropical (warm summer) regions. Bijnor of experiences all three season. The summer season is from April to June with the maximum temperature ranging between 40-42.5^{0}C. The south west monsoon (popularly known as monsoon) begins in early June and last till September. The winter season falls in the months of December, January and February. Temperature in the cold weather could drop to freezing with maximum at almost 10-12^{0}C. Bijnor also witnesses severe fog in January resulting in massive traffic and travel delays. It may small snow in Bijnor lowest temperature recorded 1.5^{0}C & Highest 45^{0}C. (Department of Agricultural, Bijnor).

3.1.4 Rainfall

Bijnor district comes under sub-tropical climate receiving the mean annual rainfall about 1106.85 mm and average annual rainfall of India is 1190 mm. Major rains were received from June to end of September. India receives adequate amount of rainfall annually through the four different types of weather phenomena viz., south west monsoon (74%), North – east monsoon (3%), Pre- monsoon (13%), and Post – monsoon (10%). The climate is generally tropical monsoon, but variations exist due to difference in altitudes.

3.1.5 Land

Uttar Pradesh can be divided in to three distinct geographical region; a (the Himalayan region in the north). b (the Gangetic Pain in the centre) and c (the Vindhya Hills and plateau in the south). Bijnor comes under the indo–Gangetic Plains. The Gangetic Plain in the centre- highly fertile alluvial soils; Gentle Plain topography broken by numerous ponds, lake and Rivers; slop 0.2 m/km.
The indo –Gangetic belt is the world's most extensive expanse of uninterrupted alluvium formed by the deposition of silt by the various rivers. The plains are plan and mostly trees, making it conducive for irrigation through canals. The area is also rich in ground water sources. The plains get their names from the rivers Ganges and Indus.

Fig.3.1a Geological map of Utter Pradesh state

The land of the Bijnor District; which is especially suitable for the production of sugarcane,wheat Rice. Maize,Potato, Bajra and Arahar, etc.

3.1.6 Agriculture

India is particularly rich in varieties of natural resources. The plains are one of the world's most intensely farmed areas. In the Uttar Pradesh 168.12 (lakh. ha) area are cultivated. Crops grown in the Bijnor district are primarily sugarcane and wheat, grown in rotation. Other crops include Rice, Maize, Potato, Bajra, Arahar, etc.

3.2 Data collection

Yearly Rainfall data of 20^{th} year (1990-2009) was collected from **"Department of Agriculture Bijnor District (U.P)"** and utilize for analysis.

3.3 Estimations of the recurrence interval

The recurrence interval is the average time interval that elapses between the two events that equal or exceed a particular level. It is also known as return period. The available rainfall data of years (1990-2009) is arranged in descending order.The recurrence interval (T) and rank number (m) is calculated by the **Weibull's**

Formula (1939).

$$T = \frac{(N+1)}{m} \qquad \text{………………3 .1}$$

Where,

T = is the return period (in years).
m = rank number of rainfall even after arranging in descending order.
N = total number of years for which the data (1990-2009) are available.

3.4 Estimations of percentage probability

The probability of an event is the chance that it will occur when an observation of the random variable is made. It is the inverse of recurrence interval. Probability is denoted by "p". It is express as a per–cent age.

$$P = \frac{1}{T} 100 \qquad \text{………..……3.2}$$

3.5 Statistical parameters

The following statistical parameters were calculated to evaluate the probability analysis for prediction of annual maximum rainfall of Bijnor District. The following statistical parameters were used.

3.5.1 Mean

The mean of annual rainfall for the years (1990-2009) were calculated. The following formula was used to evaluate.

$$\overline{X} = \frac{\sum X}{N} \qquad \text{…………..……3 3}$$

Where,

$\overline{X}$ = mean of the rainfall.
ΣX = sum of the rainfall.
N = total number of rainfall.

3.5.2 Standard deviation (SD)

The standard deviation (SD) of the probability analysis and prediction of annual maximum rainfall for the years (1990-2009) were calculated. The following formula was used to evaluate.

$$\sigma_n = \sqrt{\frac{\sum(X - \overline{X})^2}{N - 1}} \qquad \text{………..……3. 4}$$

Where,
σ_n = standard deviation, which is a function of sample size.
N = total number of rainfall (1990-2009).
$\overline{X}$ = mean of rainfall (1990-2009).

3.5.3 Co-efficient of skewness (Cs)

The co-efficient of skew ness **(Cs)** of the probability analysis for prediction of annual maximum rainfall for the years 1990-2009 were calculated. The following formula was used to evaluate.

$$Cs = N \sum (Z - \overline{Z})^3 / (N - 1)\, (\sigma_n)^3 \ \ldots 3.5$$

Where,
Z = log value of the rainfall data.
= mean value of the rainfall data.
N = sample size.
σ_n = standard deviation.

3.6 Probability of occurrence of rainfall

Probability of occurrence of rainfall after the estimated probability analysis was calculated with the following formula. The product of standard deviation and frequency factor (k) can be positive or negative, large or small, irregular and variable. It expressed as.

$$\chi_t = \overline{X} + K \text{ x } \sigma_n \qquad \text{……3. 6}$$

Where,

χ_t = rainfall amount for return period of "T" years.
$\overline{X}$ = the mean of rainfall data.
σ_n = standard deviation(SD).

K = frequency factor which depends upon the return periods "T".

3.7 Comparison of three rainfall probability distribution models

The following formula were used to evaluate rainfall probability distribution models viz. Gumbel, Log Pearson Type-III and Log Normal at **(28.57, 52.36, 76.34 and 95.24**) per-centage levels. The calculations were given below.

3.7.1 Gumbel distribution

Gumbel (1954) developed one of the most widely used distribution model for rainfall analysis of floods, annual maximum rainfall etc.

The following steps were used to analyze the annual maximum rainfall probability distribution.

i. Means of annual rainfall were calculated.
ii. Standard deviation (σ_n) were calculated by the given formula.
iii. Using appendix table A and table B determine Y_n and S_n appropriate given N.
iv. Reduced variate was calculated for folly formula.

$$y_t = -\left(\ln \ln \frac{T}{T-1}\right) \qquad \text{.................}37$$

Where

y_t= reduced variate, a function of "T".

T = recurrence interval in years.

(v) Frequency factor of Gumbel distribution was calculate for the following formula

$$K = \frac{y_t - y_n}{S_n} \qquad \text{...............}3\ 8$$

Where,

y_t = reduced variate, a function of "T".

Both Y_n (reduced mean) and S_n (reduced standard deviation) are function of sample size N and its values are available in tubular form for various values of N **(Subramanya, 1984).**

(vi) Predicted rainfall was calculated by the formula given as below.

$$\chi_t = \overline{X} + K \, x \, \sigma_n \quad \text{....... ....}3.\ 9$$

Where,

$\overline{X}$ = mean of rainfall data.

χ_t = predicted rainfall amount for return period of "T" years.

K = frequency factor of Gumbel distribution.

σ_n = standard deviation (SD).

3.7.2 Log Normal Distribution

Chow (1964) was derived the frequency factor for the Log Normal distribution. In this method, the sample (i.e. X in this case) is first transformed into logarithmic form before analyzing when the **Cs** is zero, i.e. Cs= 0, the Log Pearson type-III distribution logarithmic form reduce to Log Normal Distribution. These steps were taken by the Log Normal Distribution which is given below.

$$Y_t = \overline{Y} + K_x \, y \, \sigma \qquad \text{.......}3.\ 10$$

Where,

T = recurrence interval of years.

Kx = frequency factor of Log Normal distribution.

σ_n = standard deviation.

i. $\log_{x=Y}$ of all rainfall was taken.
ii. $\overline{Y}$ (Mean of log values) was calculated.
iii. (Y-$\overline{Y}$) was calculated.
iv. (Y-$\overline{Y}$)^2 was calculated.
v. (Y-$\overline{Y}$)^3 was calculated.
vi. Standard deviation (σ_n) was calculated by the formula.
vii. Coefficient of skeness (Cs) was taken zero for Log Normal distribution (appendix C)

viii. The value of frequency factor (Ky) was taken from the statistical table (Appendix C) Corresponding to C_S to T (recurrence interval). Thus

ix. Predicted rainfall was calculated as

y_t = antilog (y_t). ……. 3.11

3.7.3 Log Pearson type III distribution

In this method, the sample (i.e. Z in this case) is first transformed into logarithmic form before analyzing. For Log Pearson type-III distribution, Kz is a function of which were calculated by both the return period and the coefficient of skew ness. The value of Kz are given by **Water Resources Council (1967)** shown in appendix table C. These steps was taken for Log Pearson type- III distribution.

$$Z_t = \overline{Z} + K_z \text{ x } \sigma_n \qquad \text{..........3. 12}$$

Where,

T = recurrence interval of years.
Kz = frequency factor of Log Pearson type-III distribution.
σ_n = standard deviation.

i. Log_x = Z of all rainfall data was taken.

ii. $\overline{Z}$ (Mean of the log values) was calculated.

iii. (Z- $\overline{Z}$) was calculated.

iv. (Z- $\overline{Z}$)^2 was calculated.

v. (Z- $\overline{Z}$)^3 was calculated.

vi. Standard deviation (σ_n) was calculated by the formula.

vii. Co-efficient of skewness (Cs) was obtained from the formula.

viii. The value of frequency factor (Kz) was taken from the statistical table (Appendix D) corresponding to Cs to "T" (recurrence interval). Thus

ix. Predicted rainfall was calculated.

χ_t = antilog (Z_t) ……. 3.13

IV. Result And Discussion

Predicted (Gumbel, Log Normal and Log Pearson type – III) annual maximum rainfall.

The estimated predicted annual maximum rainfall at different probabilities is presented in table 1. The data computed Chi-square values for the three probability distribution were less than the critical Chi – square value at 95% confidence level for predicted annual (except for Log Pearson type – III distribution). It is seen from the table 2 that the sum of χ^2 value was minimum (32.983) for Gumbel distribution which reveals that overall accuracy of the model for expected rainfall. But when the χ^2 values were compared individually the result obtained was better prediction at 52.36% and 28.57% probability of exceedance for Log Normal distribution. Gumbel predicting the rainfall very near to observed value.

4.2.2 Average annual maximum rainfall.

The result of average annual rainfall is presented in table 2 revealed that the computed Chi-square values for the three probability distributions were less than the critical chi – square values at 95% confidence level for predicted annual maximum rainfall. The χ^2 value (32.983) was least for Gumbel distribution which showed that the Gumbel distribution χ^2 as better than other Distribution. The Log Normal and Log Pearson type – III distribution at 52.36% and 76.34% also gives better results when compared individually. Gumbel distribution was predicting the rainfall very near to the observed rainfall.

Comparison of observed rainfall and predicted rainfall by Gumbel distribution.

It is clearly indicated; we found that the comparison between observed annual maximum rainfall and predicted annual maximum rainfall by Gumbel distribution is nearly to the observed annual maximum rainfall. Coefficient of determination for predicted annual maximum rainfall is (R2= 9141).

Comparison of observed rainfall and predicted rainfall by Log Normal distribution.

It is clearly indicated, we found that the comparison between observed annual maximum rainfall and predicted annual maximum rainfall by Log Normal distribution. The Log Normal distribution is semi closed to the observed annual maximum rainfall. The coefficient of determination for predicted, annual maximum rainfall is (R2= 0. 6777).

Comparison of observed rainfall and predicted rainfall by log Pearson type III distributions.

It I clearly indicated we found that the comparison between observed annual maximum rainfall and predicted annual maximum rainfall by Log Pearson type- III distribution is not closed, this model is not suitable for predicted rainfall and observed annual maximum rainfall.. The coefficient of determination for predicted, annual maximum rainfall is (R^2 = 0.7343).

Table 1. Comparison Of Observed And Predicted Annual Maximum Rainfall By Gumbel Distribution Model.

Rainfall years	Observed rainfalls (mm)	Predicted rainfall (mm)
1990	1741.3	1746.472
1991	467.5	607.556
1992	384.5	506.605
1993	582.2	948.217
1994	1079.6	975.891
1995	1203	1127.903
1996	1478.6	1478.698
1997	1305	1314.214
1998	1906.3	1786.619
1999	974	880.397
2000	1320	1394.897
2001	712.1	733.063
2002	1080.5	1024.223
2003	960.6	832.455
2004	1025.5	929.898
2005	1491.5	1593.681
2006	1161.5	1074.504
2007	1258.2	1246.004
2008	1241.8	1186.758
2009	763.4	780.615

Table 2 Comparison of observed and predicted annual maximum rainfall by Log Normal distribution model.

Rainfall years	Observed rainfalls (mm)	Predicted rainfall (mm)
1990	1741.3	1768.998
1991	467.5	1108.336
1992	384.5	1103.719
1993	582.2	1112.044
1994	1079.6	1156.549
1995	1203	1202.33
1996	1478.6	1461.757
1997	1305	1300.497
1998	1906.3	2028.588
1999	974	1470.659
2000	1320	1362.746
2001	712.1	1118.095
2002	1080.5	1169.17
2003	960.6	1129.825
2004	1025.5	1146.933
2005	1491.5	1643.685
2006	1161.5	1202.333
2007	1258.2	1257.781
2008	1241.8	1226.669
2009	763.4	1123.241

Table 3 Comparison Of Observed And Predicted Annual Maximum Rainfall By Log Pearson Type III Distribution Model**.**

Rainfall years	Observed rainfalls (mm)	Predicted rainfall (mm)
1990	1741.3	1383.958
1991	467.5	1181.436
1992	384.5	1179.958
1993	582.2	1182.917
1994	1079.6	1195.826
1995	1203	1208.876
1996	1478.6	1276.294
1997	1305	1235.405
1998	1906.3	1403.742
1999	974	1190.347
2000	1320	1257.497
2001	712.1	1184.4

2002	1080.5	1199.326
2003	960.6	1187.865
2004	1025.5	1192.835
2005	1491.5	1319.087
2006	1161.5	1203.338
2007	1258.2	1224.111
2008	1241.8	1215.454
2009	763.4	1185.883

V. Conclusions

The annual maximum rainfall at Bijnor District was **1746.472 mm, 1768.998mm, 1383.958mm, 1741mm** for predicted annual maximum rainfall and observed annual maximum rainfall respectively. The statistical comparison at **(28.57 %, 52.36%, 76.34% and 95.24%)** by Chi-square test **(Hoggo and Tanis 1977)** of goodness of fit. It is clearly indicates the Gumbel distribution was very near to the observed annual maximum rainfall and predicted annual maximum rainfall (mm). Log Normal and Log Pearson type-III distribution was found to be best model for predicted annual maximum rainfall and observed annual maximum rainfall (mm). The coefficient of determination for predicted, annual maximum rainfall was **(0.9141, 0.6777, and 0.7343)** close to 1 which showed better dependence of predicted annual maximum rainfall on observed annual maximum rainfall the coefficient value of determination tends towards zero.

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