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Ranking of Plotting Position Formula in Frequency Analysis of Annual and Seasonal Rainfall at Gariyaband, Chhattisgarh

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Abstract: The frequency of recurrence of observed distributions is crucial in frequency analysis of hydrologic data for the purpose of plotting observed data, often known as "plotting positions." The appropriate determination of plotting positions has consistently been a contentious topic of conversation. Throughout time, a variety of methods for computing plotting positions have been presented. Through error statistics such as Mean Square Error (MSE), Root Mean Square Error (RMSE), and Mean Absolute Error (MAE), eight plotting position functions, which involves Hazen, California, Weibull, Beard, Chegodayev, Blom, Gringorten, and Cunnane, have been evaluated in this study for whether they could accurately estimate the magnitudes of annual and seasonal rainfall at Gariyaband district in Chhattisgarh state. Rankings are given to the methods for plotting position based on the that comes before error statistics. In accordance with an evaluation of the effectiveness of different plotting positions investigated in the study in terms of best estimation of magnitudes of seasonal and annual rainfall at Gariyaband District, Chhattisgarh, it is observed that the Cunnane method achieves the overall ranking "1," followed by the Gringorten method. Subsequently, the Cunnane technique is suggested as the best plotting position formula in frequency analysis of hydrologic data in Gariyaband District of Chhattisgarh State.

Keywords: Rainfall, Chhattisgarh, Plotting Position, Rainfall Analysis, Frequency Analysis

1. Introduction

Rainfall is a crucial natural resource which serves as a direct/indirect input for crop water requirements as well as an indirect input for regulating accommodation commercial, and industrial water demands via surface and subsurface storage. At different times and in different places, it rains in diverse amounts. In order to develop water resources generally over a longer period of time, it must be investigated the historical long-term annual and seasonal rainfall of any location or region. Singh (1994) [17]

One of the most serious obstacles in hydrology is to estimate the probability of occurrence using historical records of hydrological events. The projected rainfall can be forecasted with a range of probabilities of occurrence by utilizing probability and frequency analysis of rainfall data. Stedinger *et al* (1993) [18]

To visualise the yearly maximum hydrologic series graphically and assess the probabilities of series exceedance, probability plotting places are utilised. Probability charts can be used to assess the degree of fit offered by various parametric flood frequency models. Additionally, they offer a non-parametric method of estimating the probability distribution of the data by either manually or automatically drawing a line between the indicated points. These exceptional qualities helped the graphical method gain respect from many hydrologists and engineers. It has been applied frequently when exploring hydraulic engineering and water resources. Adamowski (1981) [1], Guo (1990) [9], Rigdon (1989) [16].

As evidenced by the rising attention in recent literature Makkonen (2006) [14], Murugappan (2017) [15], Cook (2011) [7] observed that there are numerous practical analytical approaches available, including Bayesian methodology and maximum probability, and that practitioners have become used to using modern software that uses graphical estimating methods. Graphical estimations provide an exceptional chance for communicating statistical information with non-statisticians, particularly in crucial situations, due to the fact that they allow for a visual assessment of the fit of the chosen model and provide a good explanation of the results that were accomplished. Kim *et al.* (2012) [11], Lozano *et al*. (2014) [12], Makkonn (2006) [13]

For many years, statisticians and hydrologists have debated the positions of probability maps. For the examination of extreme values, a variety of plotting-position methodologies as well as related numerical techniques have been presented. The mean square error (MSE) for an objective charting approach should be the lowest of all the estimates. Cunnane (1978) [8]

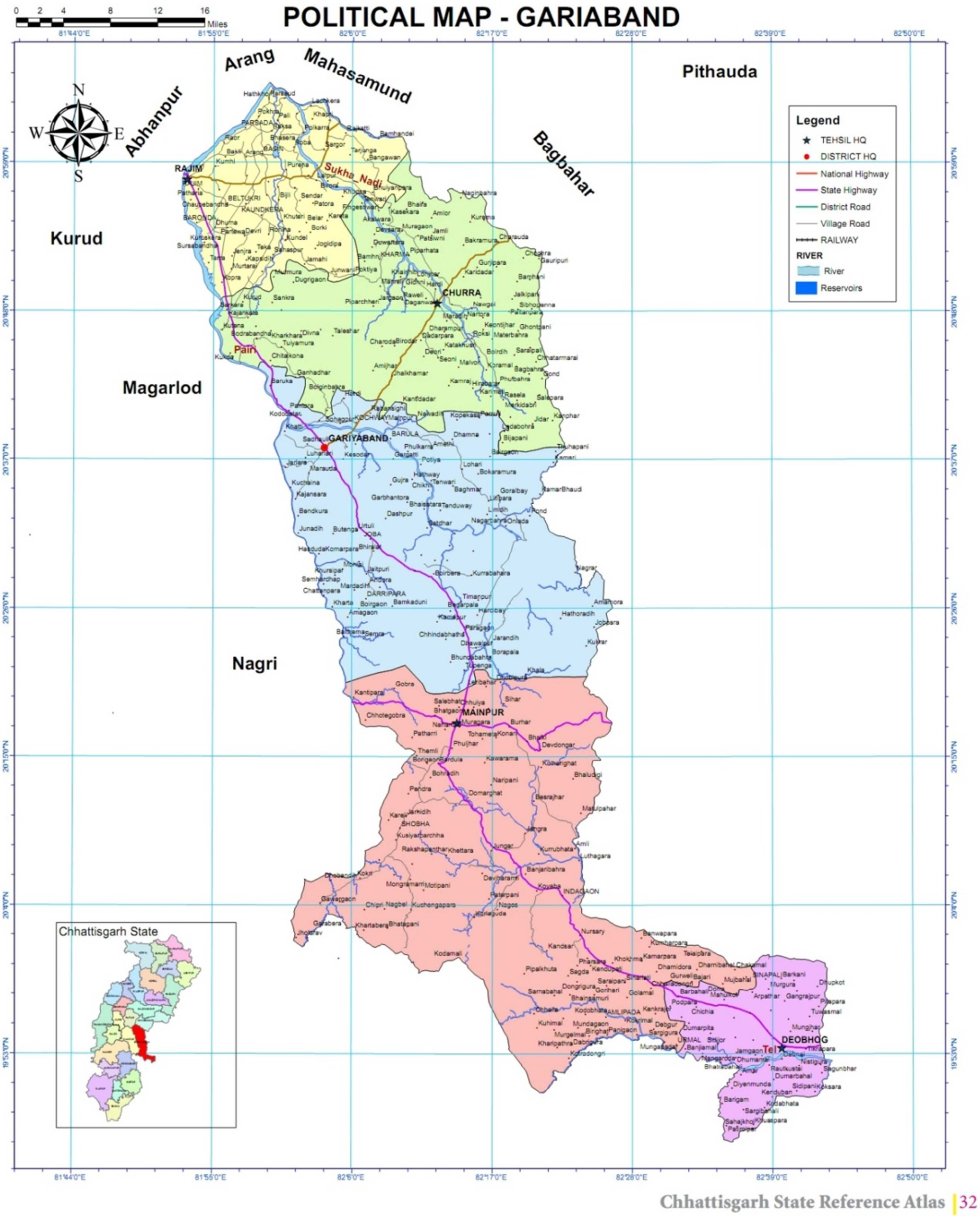

Figure 1. Map of Gariyaband district.

2. Materials and Methods

2.1. Study Area

The Chhattisgarh plains region is where Gariaband is situated. The vicinity is located at an elevation of 340m above mean sea level between latitudes N 20˚57'46" and 20˚17'36" and longitudes E 82˚53'05" and 81˚53'05". It was constituted from the Raipur district on January 1, 2012, and its headquarters are 90 kilometres south of Raipur. This district is bordered to the north by Raipur, to the west by Dhamtari, and to the east by Orrisa State. Anonymous (2014) [4] The overall gross cropped area in the Gariyaband district is expected to be 157872 hectares in 2020-21, while the net cropped area is approximately 136110 ha. The district has a total land area of 582286 hectares. The kharif area of the district was 136103 hectares. Anonymous (2021) [5]

2.2. Plotting Positions

Plotting-position equations come in many forms, some of the more well-known ones are listed in Table 1. Each of these formulas can be stated in the generic form, according to Adamowski (1981) [1].

$$P = \frac{m-a}{N+b} \tag{1}$$

where a and b are constants, P is the probability of the exceedance. m is the rank of N ordered observations (in decreasing order).

The statistics conveys rainfall over a 32-year period (1990-2021) and are presented in decreasing order of magnitude. A rank has been assigned to each parts of data. The data with the greatest value were given the rank 1 (m = 1) and the data with the lowest magnitude were given the rank N (m = N) when there were 32 data points in the sample. This arrangement gives an approximate estimate of the exceedance probability, or the probability that a value will be larger than or equal to the ranked value. A graphical plot of the probability of exceedance, P, as determined by the specified plotting-position formula, vs. the obtained rainfall, R, is produced with variables on the y axis in logarithmic scale. [2, 3]

Table 1. *Commonly used Plotting-position Method.*

Plotting-Position method	Formula for probability of exceedance, P	a	b	Return period, T
Hazen (1914)	$\frac{m-0.5}{N}$	0.5	0.0	$\frac{N}{m-0.5}$
California (1923)	$\frac{m}{N}$	1.0	0.0	$\frac{N}{m}$
Weibull (1939)	$\frac{m}{N+1}$	0.0	1.0	$\frac{N+1}{m}$
Beard (1943)	$\frac{m-0.31}{N+0.38}$	0.31	0.38	$\frac{N+0.38}{m-0.31}$
Chegodayev (1955)	$\frac{m-0.3}{N+0.4}$	0.30	0.40	$\frac{N+0.4}{m-0.3}$
Blom (1958)	$\frac{m-0.375}{N+0.25}$	0.375	0.25	$\frac{N+0.25}{m-0.375}$
Gringorten (1963)	$\frac{m-0.44}{N+0.12}$	0.44	0.12	$\frac{N+0.12}{m-0.44}$
Cunnane (1978)	$\frac{m-0.4}{N+0.2}$	0.40	0.20	$\frac{N+0.2}{m-0.4}$

The observed annual rainfall levels, R, and the likelihood that they will exceed them, P, are connected in a way that makes the probabilities the x-values and the observed values the y-values. A logarithmic scale is used for x axes. The degree of goodness of fit that was so reached is shown by the gained r2 value. The analysis that follows determines how well any plotting-position approach fits the measured values of rainfall.

The precise plotting-position approach described above can be used to calculate the chance of exceeding, P, the observed rainfall magnitudes during the 32 years of historical data (1990-2021). The error statistics are then computed as follows, including Mean Square Error (MSE), Root Mean Square Error (RMSE), and Mean Absolute Error (MAE).

$$MSE = \sum_{i=1}^{N} \frac{1}{N}\left(R_{p\,i} - R_i\right) \tag{2}$$

$$RMSE = \sqrt{\sum_{i=1}^{N} \frac{1}{N}\left(R_{p\,i} - R_i\right)} \tag{3}$$

$$MAE = \sum_{i=1}^{N} \frac{1}{N}\left(\left|R_{p\,i} - R_i\right|\right) \tag{4}$$

Every among the eight plotting-position techniques listed in Table 1 is utilised in the procedure described aforementioned. The error statistics provided above are used to evaluate the performance of each of the plotting - position equations. The several plotting-position techniques for determining rainfall magnitudes will be ranked using this performance evaluation method.

The plotting-position equations are rated based on the error statistics discussed in this section. The method with the lowest MSE receives the rank "1," while the method with the highest MSE receives the rank "8." The same method is used to rank techniques based on RMSE and MAE.

The overall ranking of each methodology in terms of MSE, RMSE, and MAE is calculated. The average of all the rankings given to a plotting-position method in terms of the three statistics, namely MSE, RMSE, and MAE, is used to determine the method's mean ranking. The approach with the lowest mean ranking receives an overall ranking of "1," whereas the method with the greatest mean ranking receives an overall ranking of "8."

The performance of each plotting-position approach will be evaluated for estimating annual rainfall, south-west monsoon rainfall, and north-east monsoon rainfall with varying probabilities of exceedance.

3. Result and Discussion

3.1. Fundamental Statistics of Historic Rainfall Data

The annual and seasonal rainfall records of Gariyaband throughout the 32-year period (1990-2021) are summarised in Table 2 in their respective fundamental statistical terms.

Table 2. *Fundamental statistics of seasonal and annual rainfall over Gariyaband.*

Month	Mean (cm)	Max (cm)	Min (cm)	SD (cm)	CV (%)	Skewness
Annual	126.7	194.4	91.0	27.1	21.4	0.8
North-east monsoon	7.0	36.2	0.0	7.2	102.9	2.3
South-west monsoon	114.3	163.7	83.1	23.9	20.9	0.5
Summer	4.6	18.4	0.0	5.3	115.3	1.5
Winter	0.9	5.4	0.0	1.4	164.9	2.2

The maximum and minimum annual rainfalls were 194.4 cm and 91 cm in 1990 and 2000, respectively. Roughly two thirds and a third of the yearly rainfall in the study area are contributed by the South-West and North-East monsoons, respectively. The amount of rain that typically occurs during the North-east and South-West monsoons accounts for around 90% of the mean annual amount, while the average rainfall throughout the summer and winter only accounts for 10%. Although it was more than 100% for rainfalls during the summer and winter (115.3% and 164.9%, respectively), the coefficient of variation for yearly rainfalls during the South-West and North-East monsoons was found to be 21.4%, 20.9%, and 102.9%, respectively. As stated by Bulmer (1979) [6], Distribution that is mostly symmetrical is indicated by skewness between -0.5 and +0.5. For the 32-year period from 1990 to 2021, the distribution is not symmetrical, and the skewness of the annual rainfall (0.8) and North-West monsoon rainfall (2.3) is not between -0.5 and +0.5.

3.2. Error Statistics

The 32 years of historical data (1990-2021) for each of the plotting-position equations presented in table 1 were used to calculate the probability of surpassing the recorded rainfall magnitudes, or Pm. With the use of 32 years of data, the estimation of rainfall magnitudes with varied exceedance probabilities was then made for all eight plotting-position equations, and projections of annual rainfall, north-east monsoon rainfall, and south-west monsoon rainfall were made. To calculate the MSE, RMSE, and MAE error statistics, the estimated rainfall magnitudes were compared to the corresponding observed rainfall magnitudes. Murugappan (2017) [15]

Table 3 present the calculated error statistics for different plotting-position methods used to estimate annual rainfall, south-west monsoon rainfall, and north-east monsoon rainfall.

Table 3. *Error statistics in estimation of South-West monsoon, North-East monsoon and annual rainfall for various plotting-position.*

Plotting Position	South-West monsoon			North-East monsoon			Annual		
	MSE	RMSE	MAE	MSE	RMSE	MAE	MSE	RMSE	MAE
Hazen	194.7	14.0	12.5	71.4	8.5	5.8	83.3	9.1	6.0
California	96.0	9.8	9.7	7.3	2.7	2.0	34.6	5.9	4.2
Weibull	105.7	10.3	10.2	8.1	2.8	2.1	38.0	6.2	4.4
Beard	271.5	16.5	14.1	7.6	2.8	2.0	93.2	9.7	5.7
Chegodayev	98.5	9.9	9.8	2.1	1.5	1.2	34.2	5.8	4.0
Blom	96.4	9.8	9.7	7.6	2.8	2.1	34.8	5.9	4.2
Gringorten	172.5	13.1	12.5	0.0	0.0	2.0	60.2	7.8	5.1
Cunnane	9.7	3.1	9.7	2.0	1.4	2.0	4.2	2.0	4.2

The probability of exceeding the observed rainfall magnitudes, Pm, was computed using the 32 years of historical data (1990–2021) for each of the plotting-position equations shown in table 1. The estimation of rainfall magnitudes with varying exceedance probabilities was then determined for all eight plotting-position equations using 32 years of data, and predictions of annual rainfall, north-east monsoon rainfall, and south-west monsoon rainfall were attained. The estimated rainfall magnitudes were compared to the corresponding observed rainfall magnitudes in order to determine the error statistics, namely MSE, RMSE, and MAE.

In Table 4, the approaches for estimating annual rainfall magnitudes, South-West monsoon rainfall, and North-East monsoon rainfall with varying probabilities of exceedance are ranked by their likelihood of exceeding.

The Cunnane approach routinely outperforms other methods, earning it first place for best estimation of yearly rainfall, south-west monsoon rainfall, and north-east monsoon rainfall with varying probability of exceedance. The Chegodayey method estimates yearly precipitation with a grade of "2" overall, Gringorten for precipitation from the North-east monsoon, and California for precipitation from the South-West monsoon. While Beard technique achieved a "8" overall grade in estimation of annual and south-west monsoon rainfalls, Hazen approach earned a "8" overall rating in estimation of the North-East monsoon. Most of the methods evaluated in this study estimated rainfall amounts with shorter return times to within 5% of the actual value. (Range: from 1.2 years to 20 years). The estimates of rainfall magnitudes with larger return periods (> 20 years) were shown to be exaggerated by more than 10% by the various approaches, compared to the observed values. This was particularly true for rainfall magnitude estimates with return periods of less 1.2 years. Makkonen [8] compared the return period of the largest value in a sample of 21 annual extreme values determined by the numerical method proposed by Harris [10], The highest yearly extreme event's return period was underestimated by all other approaches, according to the Weibull method, Beard, Gringorten, and Hazen, which reported a percentage error in estimation of the event of zero for the Weibull method.

Table 4. *Ranking of plotting-position methods in estimation of magnitudes of South-East monsoon, North-East monsoon and annual rainfall with different probability of exceedance.*

Plotting Position	South-West monsoon			North-East monsoon			Annual		
	MSE	RMSE	MAE	MSE	RMSE	MAE	MSE	RMSE	MAE
Hazen	7	7	7	8	8	8	7	7	8
California	2	2	2	4	4	2	3	3	2
Weibull	5	5	5	7	7	7	5	5	5
Beard	8	8	8	5	5	5	8	8	7
Chegodayev	4	4	4	3	3	1	2	2	1
Blom	3	3	3	6	6	6	4	4	4
Gringorten	6	6	6	1	1	3	6	6	6
Cunnane	1	1	1	2	2	4	1	1	3

4. Conclusion

In terms of error statistics, it shows that the Cunnane technique receives the overall ranking "1" based on the evaluation of the performance of various plotting locations studied in the study in best estimating the magnitudes of annual and seasonal rainfall at Gariyaband District, Chhattisgarh. Given that the data are distributed normally or roughly normally, the Cunnane technique is advised as the optimal plotting position formula in frequency analysis of hydrologic data.

References

[1] Adamowski, K. (1981). “Plotting Formula for Flood Frequency.” Water Resource. Bulletin, 17 (2): 197-202.

[2] Adeboye, O. B., and Alatise, M. O. (2007). Performance of probability distributions and plotting positions in estimating the flood of River Osun at Apoje Sub-basin, Nigeria. Agric. Eng. Int.: CIGR J., 9.

[3] Ani shabri. (2002). “A comparison of plotting position formulas for the Pearson Type III distribution”, Jurnal Teknologi, 36 (C) Jun. 2002: 61–74, Universiti Teknologi Malaysia.

[4] Anonymous. (2014), Agriculture Contigency plan for District – Gariyaband, ICAR, http://www.nicraicar.in/nicrarevised/images/statewiseplans/Chattisgarh/CHH23-Gariyaband-30.08.2014.pdf.

[5] Anonymous. (2021), District socio-economic data brochure, District Planning and Statistics, Gariyaband, 3-4B.

[6] Bulmer, M. G. (1979). “Principle of Statistics”. Dover Publications, 252 pp.

[7] Cook, N. (2011) Comments on Plotting Positions in Extreme Value Analysis. J. Appl. Meteorol. Climatol, 50, 255-266.

[8] Cunnane, C. (1978). “Unbiased Plotting Positions- A Review.” Journal of Hydrology, 37: 205-222.

[9] Guo, S. L. 1990. A Discussion On Unbiased Plotting Positions For The General Extreme Value Distribution, Journal of Hydrology. 121: 33-44.

[10] Harris, R. I. (1996). “Gumbel re-visited—A new look at extreme value statistics applied to wind speeds”, J. Wind Eng. Ind. Aerodyn., 59, 1–22.

[11] Kim, S., Shin, H., Joo, K., and Heo, J. H. (2012) Development of plotting position for the general extreme value distribution. J. Hydrol., 475, 259-269.

[12] Lozano-Aguilera, E. D., Estudillo-Martínez, M. D., and Castillo-Gutiérrez, S. (2014) A proposal for plotting positions in probability plots. J. Appl. Stat., 41, 118-126.

[13] Makkonen, L. (2006). “Plotting Positions in Extreme Value Analysis”, Journal of Appl. Meteorol. and Climatol., 45, pp. 334 – 340.

[14] Makkonen, L. (2008) Problems in the extreme value analysis. Struct. Saf., 30, 405-419.

[15] Murugappan, A., Sivaprakasam, S. and Mohan. S. (2017) Ranking of plotting position formulae in frequency analysis of annual and seasonal rainfall at Puducherry, South India, Global Journal of Engineering Science and Researches, July 2017: 67-76.

[16] Rigdon, S. E., and Basu, A. P. (1989) The power law process: a model for the reliability of repairable systems. J. Qual. Technol., 21, 251-260.

[17] Singh, V. P. (1994). “Elementary Hydrology”. Prentice Hall. 973 pp.

[18] Stedinger, J. R., Vogel, R. M., and Foufoula, G. E. (1993). “Frequency Analysis of Extreme Events.” Handbook of Applied Hydrology. Mc-Graw Hill Book Co., New York, Chapter 18.