



Flood Frequency Analysis of River Kafin Hausa, at Kafin Hausa, Jigawa State Nigeria

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ABSTRACT

Kafin Hausa River is one of the tributaries of the Hadejia River. It is one of the major Rivers in the Hadejia-Jama'are-Komadugu-Yobe River Basins that is vital to the livelihood of the growing population of northern Nigeria and a major water resource. Fouty six years of annual maximum series data (1976-2021) of streamflow for Kafin Hausa station were subjected to goodness-of-fit test using five probability distributions (normal, log-normal, Pearson type III, generalized extreme value type I and Gumbel) in order to establish the best-fit distribution of the data set. Log Pearson type III was found to provide the best fit and was subsequently used to carry out flood frequency analysis The predicted discharge for 2, 5, 10, 25, 50, 100 and 200years return periods are 33.11, 41.69, 45.70, 48.27, 49.65, 50.59, and 51.25 m³/s respectively. It was concluded therefore that Log Pearson type III distribution model is the best model and can therefore be used for flood estimation and design of hydraulic structures along the Kafin Hausa River.

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INTRODUCTION

Flood frequency analysis is a statistical approach used to determine the magnitude of a flood event with a certain occurrence probability or return period (Wright *et al.*, 2020). It can be based either on observed flood data only, at the site of interest or from one or several gauged basins within the same region where local data is available. In some instances, a short data record may be extended by model simulation with which frequency analysis can be performed on the data (Wilson *et al.*, 2011).

Flood frequency analyses allow the prediction of likely flood magnitude over a certain period and help in the estimation of the frequency with which a flood may occur. It is a vital tool for assessing flood risk in different regions over the globe and involves the statistical analysis of flood data such as peak discharge, flood volume, and the probability of floods of different magnitude occurring in a specific location. Flood frequency analysis is among the important areas of research in the hydrology of Rivers, which is constantly conducted based on streamflow data (Ntajal, 2016). Khaliq *et al.*, (2006) highlighted the important steps in conducting flood frequency analysis as first finding the probability distribution function that suitably fit the data set, then obtaining the parameter of the data set based on the selected probability distribution function, and finally establishing the uncertainty at a defined confidence level.

Although the use of probability distribution in hydrology is not a new phenomenon, several studies have used probability models to fit in raw data from the past till date. Chow et al., (1990) highlighted that it can be used when estimating extreme events with a return period greater than the length of the record. Idris (2015) reported that, although a variety of statistical distributions are available and commonly applied for flood frequency analysis, however, there is no justification for selecting a particular probability distribution other than their flexibility in mimicking the shape of an observed statistical distribution. Cunnane (1989) reported the significance of using the wrong form of the distribution as the over design or under design of hydraulic structures which is undesirable. Therefore, since the right

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probability distribution of the data set is unknown, the selection of a precise distribution is paramount.

Location **Probability Distribution** Reference Investigated Recommended Iraq Younis et al., Log Normal and Log Log-Normal (2019) Pearson Type III Bhat et al., (2019) Gumbel and Log Log Pearson Type III Kashmir Pearson Type III Hussain (2009) Pakistan Generalized Normal, Pearson Type III Generalized Logistic, Generalized Extreme Value and Pearson Type III Abdulkarim Log Normal, Gumbel/ Generalized Extreme Bangladesh (1995) Log-Pearson Type III Value and Generalized Extreme Value Vivekanandan Exponential, Extreme Extreme Value Type I India (2015)Value Type I, Extreme Value Type II. Generalized Pareto and Normal Idris (2015) Nigeria Log-Normal (Ln), Log-Wakeby and Log-Pearson Pearson Type III (Lp3), Type III Distributions. Gumbel (Type I Extreme Value), Generalized Extreme Value (Gev), Generalized Pareto and Wakeby Distributions. Odunuga and Nigeria Log-Pearson Type III Gumbel (Type I Extreme (Lp3) and Gumbel Raji (2014) Value Distribution). (Type I Extreme Value) Distributions. Bhat et al., (2019) Kashmir Gumbel and Log Log Pearson Type III Pearson Type III Usman et al., Log-Normal (LN), Log-Log Normal Nigeria (2016) Pearson Type III (LP III) and Extreme Value (EV-I), Garba et al., Normal, Log Normal, All The Four Distributions Nigeria (2013)Log Pearson Type III Were Found to be and Gumbel Distribution Acceptable Ibeje (2020) Generalized Extreme Log Pearson Type III Nigeria Value, Log Normal, Gumbel Maximum, Generalized Pareto and Log Pearson Type III

Table 1: Review of probability distributions used in flood frequency studies

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Reference	Location	Probability Distribution			
		Investigated	Recommended		
Izinyon and Ajumuka (2013)	Nigeria	Log Normal, Extreme Value Type I and Log Pearson Type III	Log Normal and Log Pearson Type III		
Verma and Rai (2023)	India	Gumbel Extreme Value, Log Pearson Type III and Log Normal	Gumbel Extreme Value and Log Pearson Type III		
Islam and Saikar (2023)	India	Gumbel and Log Pearson Type III	Log Pearson Type III		
Jou and Mirhashemi (2023)	Iran	Normal, Log Normal, Pearson, Log Pearson Type III, Extreme Value Type I. Generalized Extreme Value and Generalized Logistics Distribution	Log Pearson Type III and Extreme Value Type I		
Bezaatpour and Rudberg (2020)	Sweden	Generalized Logistic, Generalized Extreme Value, Generalized Normal, Log Pearson Type III and Generalized Pareto Distribution	Generalized Extreme Value		
Aho e <i>t al.,</i> (2019)	Nigeria	Generalized Extreme Value, Generalized Pareto, Generalized Logistics and Log Normal Distribution	Generalized Extreme Value and Generalized Pareto		
Kumar and Jha (2024)	India	Normal, Gumbel, log Normal, General Extreme Value (GEV), Pearson III and log Pearson III	Generalized Extreme Value		
Sharma and Singh (2010)	India	Normal, Log Normal, Gumbel, Log Pearson Type III and Weibull	Log Pearson Type III		
Okeke and Ohiorobo (2017)	Nigeria	Normal, Log Normal, Log Pearson, Gumbel and Foster Type I	Gumbel and Foster Type I		
Ibrahim (2014)	Nigeria	Generalize Extreme Value, Generalize Pareto, Extreme Value Type I, Log Normal, Log Normal and Wakeby distribution	Wakeby Distribution		
He <i>et al.,</i> 2006	Germany	Gumbel and Log Pearson Type III	Gumbel Distribution		

Therefore, from Table 1, it is established that the most widely used probability distributions in hydrology when considering extreme events are: Gumbel's

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Extreme Value distribution, Normal Distribution, Log Pearson Type III distribution, Log-normal Distribution (two parameter), and Generalized Extreme Value. The specific aim of this study is to estimate discharge at Kafin Hausa station on the Kafin Hausa River, a tributary of Hadejia River.

MATERIALS AND METHODS Study area The study area is located in Northwestern part of Nigeria on Hadejia River, Kafin Hausa River is a tributary of Hadejia River. It is in semi-arid region of northern Nigeria with a land mass of 30569 km² and located between latitude 11^o 32' 08.4" N and 12^o 26' 24.8" N and latitude 8^o 07' 50.0" E and 10^o 01' 50.09" E (Shuaibu *et al.*, 2022). Figure 1 shows the map of Nigeria showing Jigawa State and the study area Kafin Hausa.



Figure 1: Location map of the study area

Data Collection

Streamflow data of the River at Hafin Hausa station were collected from Hadejia Jamaare Komadugu Yobe Trust Fund. The data consist of forty-six (46) years of daily streamflow record. The data was converted into annual maximum data and then subjected to various analyses.

Outlier Identification and Treatment

The annual maximum data was first checked for outliers before fitting to a

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The annual maximum data was subjected to outlier identification test using XLSTAT 2023. The Grubb's test for outliers/two-tailed test was conducted on the annual maximum series data.

distribution (Idris, 2015; Mohammed, 2022).

The outliers were treated following a method proposed by Vukmirovic and Pavlovic (2000) which are to remove the outlier from the sample, replace it with the second highest values of the same year.

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Flow Data to Probability Fitting the Distribution

Having identified from the literature review that the most common probability distributions used in hydrology considering extreme events include Extreme value type I, Gumbel, Log Pearson Type III, Log Normal and Normal distribution. Therefore, these distributions were considered for Kafin Hausa station data. Five most widely used probability distributions as identified from literature were used for goodness-of-fit test. Anderson-Darling, Kolmogorov-Smirnov and Chi-Square test of Goodness of fit Statistics were calculated using Easyfit software for all the chosen distributions. The best fit was determined using Least Sum of the Statistical Model Identification Criterion (LSSMIC) (Mohammed et al., 2021; Hussein and Kasim 2024). The probability distribution function graph, cumulative distribution graph, goodness of fit test, and least sum of the statistical model identification criterion (LSSMIC) were used to assess the appropriateness of each probability distribution. LSSMIC = Abs (1 - sum of statistics)1

The probability distributions used are presented as follows:

Gumbel Distribution

Gumbel (1941) introduced the extreme value distribution which is called Gumbel distribution. Gumbel distribution is sometimes also called extreme value type I (EV-I) and is one of the most commonly used distribution in flood frequency analysis. Gumbel distribution is often used for predicting extreme hydrology such as flood events (Bhagat, 2017).

Gumbel defined a flood as the largest of the 365 daily flows and the annual series of flood flow constitute a series of the largest value flows (Gulap and Gitika, 2019). According to this theory of extreme events, the probability of occurrence of an event is equal to or larger than a value X_o . Gumbel's equation is given by:

$$Y_T = \overline{Y} + kS_y$$
 2
Where

Where

Where
$$Cs = \frac{\pi 2(S-y)}{\pi 2}$$
 9
 Y_T is the estimated discharge at a given return period $t^{-1} (n-2)(s_y)^3$ 9
Where S_y is the standard deviation of the sample size probability level is computed by imputing it value into equation 16 as expressed:

 $\sqrt{\frac{2(y-y)}{N-1}}$ 3

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K is the frequency factor express as

$$K = Y_T - \frac{\overline{Y_n}}{S_n}$$
 4
In which Y_T is the reduce variate, a function of
T and is given by:
 $Y_T = -\left[\ln \ln\left(\frac{T}{T-1}\right)\right]$ 5
 $K = -\frac{\sqrt{6}\left[0.5772 + \ln\left(\frac{T}{T-1}\right)\right]}{5}$

$$K_T = -\frac{\sqrt{6}}{\pi} \left[0.5772 + ln \left\{ ln \left(\frac{T}{T-1} \right) \right\} \right] \quad 6$$

Where K_T is the frequency factor

Generalized Extreme Value

Generalized Extreme Value (GEV) distribution is used frequently in the statistical analysis of extreme events in hydrological studies. It is an established model in flood frequency analysis (Sene et al., 2001; He et al., 2015; Sampio & Costa 2021). GEV's cumulative distribution function is expressed as:

$$F(x) = \exp\left\{-\left[1 + \xi \left(\frac{x - \mu}{\sigma}\right)^{-\frac{1}{\xi}}\right]\right\} 7$$

Where μ is the location parameter, σ is the scale parameter and ξ is the shape parameter The frequency factor K in GEV distribution is a measure of the return period associated with a particular value from the distribution. The frequency factor K can be expressed as:

$$K_T = \frac{1}{1 - F(x)} \qquad 8$$

Where K_T is the frequency factor and F(x) is the cumulative frequency distribution

Log Pearson Type III

Log Pearson type III distribution is a statistical technique for fitting flow data to probability distribution to predict the design flood for a River at some site. This distribution encompasses the transformation of random variable x as Pearson Type III from natural units to logarithmic units and then computes mean, standard deviation and skewness coefficient. The expression of the mean, standard deviation and coefficient of skewness are: Skewness coefficient

$$=\frac{n\sum(y-\bar{y})^3}{(n+1)(n-2)(Sy)^3}$$

Cs

bability level is computed by imputing it value equation 16 as expressed:

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$$Y_T = \bar{y} + KS_v \qquad 10$$



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Where Y_T is the flood discharge value for some specific probability,

 \overline{y} is the average of y discharge values,

 $S_{\mathcal{Y}}$ is the standard deviation of \mathcal{Y} and K is the frequency factor

 $K_T = \frac{1}{1 - F(x)}$ 11 Where K_T is the frequency factor

The frequency factor is a function of the skewness coefficient and the return period and can be obtained from frequency factor table in standard hydrology textbooks (Chow *et al.*, 1988).

Normal Distribution

Normal distribution is a continuous probability distribution defined by two parameters; mean (μ) and standard deviation (σ).The probability density function (PDF) of normal distribution is given by:

$$F(x) = \frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$
 12

Where μ is the mean and σ is the standard deviation

 $K_T = \frac{x_t - \mu}{\sigma} \qquad 13$

Where $\overset{\sigma}{K_T}$ is the frequency factor

Log Normal Distribution

Log-normal probability is a continuous probability distribution that arises when the logarithm of a variable follows a normal distribution. Normal distribution PDF is expressed as:

$$F(x;\mu,\sigma) = \frac{1}{x\sigma\sqrt{2\pi}}e^{-\frac{(\ln(x)-\mu)^2}{2\sigma^2}} \quad 14$$

Where μ is the mean and σ is the standard deviation

 $K_T = \frac{1}{1 - F(x)} \quad 15$

Where K_T is the frequency factor

Flood Frequency Analysis

The flood frequency analysis was carried out using the Weibull plotting position formula

$$P = \frac{m}{n+1} \qquad 16$$

Where m is the order of the events and N is the total number of events in the data, T is the return period and is calculated with the equation:

$$T = \frac{1}{p}$$
 17

RESULTS ABD DISCUSSION Outlier Identification and Treatment

Grubs and Dixon test were done for the stream flow data the result shows that two of the observation were found to be outliers for both the tests. These outliers were treated by replacing the outliers with the second-highest observation value for that year, after which the test was done for the second time. Figure 2 and Figure 3 show the initial outlier test and the rerun test after the removal of the outlier from the data set.



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Figure 3: Rerun of Grubbs outlier test

RESULT OF GOODNESS-OF FIT TEST Visual identification of best-fit model

The PDF and CDF graphs of the flow data at Kafin Hausa station is shown in Figures 4 and 5.The best-fitted distribution is hardly

seen by visual identification as almost all the five selected distributions look likely to fit by visual identification,. Therefore, goodness of fit test, and LSSMIC is required to identity the best fit distribution.



Figure 4: Kafin Hausa PDF of annual maximum flow

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Figure 5: Kafin Hausa CDF of annual maximum flow

Goodness of Fit Test and LSSMIC

According to the goodness of fit tests, the probability distribution with the lowest test statistic is the best fitting distribution. The result of the Kolmogorov-Sminov, Anderson Darling and Chi-square tests of goodness of fit are shown in Table 2. Generalized extreme value provides the best fit as it is ranked 1st in the Kolmogorov-Sminov and Anderson Darlings tests. The goodness of fit test was conducted and the probability distribution with the lowest test statistic is ranked as the best fitting distribution. Table 3 shows the result of Chisquare, Anderson-darling, Kolmogorov-Smirnov test of goodness of fit, and LSSIMC for Kafin Hausa streamflow data.

Distribution Kolmogor		ov- Anderson- Darling		Chi-Square					
	Statistic	Rank	Statistic	Rank	Statistic	Rank	Sum of Statistics	LSSIMC	
Generalized Extreme Value (EV1)	0.14	1st	0.33	1st	0.31	2nd	0.78	0.22	
Gumbel	0.21	5th	1.68	5th	0.71	4th	2.60	-1.60	
Log Pearson Type III	0.15	2nd	0.43	2nd	0.32	3rd	0.90	0.10	BEST
Log-Normal	0.17	3rd	1.03	4th	1.33	5th	2.53	-1.53	
Normal	0.17	4th	0.51	3rd	0.06	1st	0.74	0.26	

Table 2: Result of Goodness of Fit Test

The goodness of fit test result shows that generalized extreme value and Log Pearson type III are close in the values of statistics where the best fit is adopted according to the lowest value of statistics. However, the goal is to obtain the best-fitting curve, which is achieved with the help of LSSMIC. From Table 2 it can be seen that the most suitable model among the five selected distributions is log Pearson type III having the least statistical value (0.10) and as such it is selected for the analysis.

Flood Frequency Analysis

Log Pearson type III probability distribution provides the best fit and it was used to carry out the flood frequency analysis. The result of the flood frequency analysis is presented in Table 3.

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Rank	Flow (Q)	Return	Exceedence	Y=Log Q	$(y-\overline{y})^2$	$(y-\overline{y})^3$	Year
(m) 4	(m°/s)	Perioa		1.67	0.04	0.01	2004
•	40.70	47.00	0.02	1.07	0.04	0.01	2001
	45.90	23.30	0.04	1.00	2.70	4.59	2000
1	40.37	10.07	0.00	1.00	2.74	4.00	2010
•	44.47	11.75	0.09	1.05	2.72	4.48	2019
)	43.40	9.40	0.11	1.64	2.68	4.39	1978
) -	42.96	7.83	0.13	1.63	2.67	4.36	2004
[42.83	6./1	0.15	1.63	2.66	4.34	2005
5	41.90	5.88	0.17	1.62	2.63	4.27	1979
9	40.90	5.22	0.19	1.61	2.60	4.19	1991
10	40.70	4.70	0.21	1.61	2.59	4.17	1999
11	40.20	4.27	0.23	1.60	2.57	4.13	1988
12	40.05	3.92	0.26	1.60	2.57	4.12	2017
13	40.00	3.62	0.28	1.60	2.57	4.11	1977
14	39.91	3.36	0.30	1.60	2.56	4.10	2018
15	39.80	3.13	0.32	1.60	2.56	4.10	1998
16	39.60	2.94	0.34	1.60	2.55	4.08	2021
17	39.30	2.76	0.36	1.59	2.54	4.05	1980
18	39.30	2.61	0.38	1.59	2.54	4.05	1994
19	38.76	2.47	0.40	1.59	2.52	4.01	2008
20	34.00	2.35	0.43	1.53	2.35	3.59	2011
21	33.90	2.24	0.45	1.53	2.34	3.58	1995
22	33.20	2.14	0.47	1.52	2.31	3.52	2002
23	32.60	2.04	0.49	1.51	2.29	3.47	1996
24	31.80	1.96	0.51	1.50	2.26	3.39	1992
25	31.07	1.88	0.53	1.49	2.23	3.32	2016
26	30.69	1.81	0.55	1.49	2.21	3.29	2015
27	30.30	1.74	0.57	1.48	2.19	3.25	1989
28	30.30	1.68	0.60	1.48	2.19	3.25	1990
29	29.74	1.62	0.62	1.47	2.17	3.20	2020
30	29.62	1.57	0.64	1.47	2.17	3.19	2009
31	29.06	1.52	0.66	1.46	2.14	3.13	2007
32	28.60	1.47	0.68	1.46	2.12	3.09	1986
33	28.30	1.42	0.70	1.45	2.11	3.06	1985
34	28.10	1.38	0.72	1.45	2.10	3.04	1987
35	27.86	1.34	0.74	1.45	2.09	3.02	2003
36	27.50	1.31	0.77	1.44	2.07	2.98	1993
37	24.60	1.27	0.79	1.39	1.93	2.69	1981
38	24.40	1.24	0.81	1.39	1.92	2.67	1997
39	19.84	1.21	0.83	1.30	1.68	2.18	2006
10	19.40	1.18	0.85	1.29	1.66	2.14	1983
11	16.50	1.15	0.87	1.22	1.48	1.80	1976
12	14.50	1.12	0.89	1.16	1.35	1.57	1984
13	14 40	1.09	0.91	1 16	1.34	1.55	2012
14	14.30	1.03	0.94	1 16	1.33	1.50	1982
45	12.32	1.07	0.96	1.10	1 19	1.30	2014
	12.02	1.07	0.00	1.00	1.10	1.00	2014
46	8.23	1.02	0.98	0.92	0.84	0.77	2013
n=46				68.02	99.16	149.67	
				Average =			

The mean, standard deviation and skewness coefficient of the station were calculated as 1.48, 0.170095 and -1.4151

respectively. The frequency factor of Log Pearson Type III distribution for the selected

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return periods (2, 5, 10, 25, 50, 100 and 200 years) was calculated and presented in Table 4.

Table 4: Frequency factor (K) values for (Cs = -1.4)

K-values for Kafin Hausa River							
T-Year	2	5	10	25	50	100	200
K Value	0.225	0.832	1.041	1.198	1.270	1.318	1.351

The predicted discharge for the various return periods of 2, 5, 10, 25, 50, 100 and 200 years for the River based on log

Pearson type III distribution was found to be 33.11, 41.69, 45.70, 48.27, 49.65, 50.59, and 51.25 m^3 /ss respectively as shown in Table 5.

 Table 5: Predicted Discharges

Return	Period	Probability P	Frequency Factor K (Cs=-	Y _T	Y _T
T(yrs)		(%)	1.40)	$= \overline{y} + KS_y$	(m3/S)
2		0.5	0.255	1.52335	33.36952
5		0.2	0.832	1.62144	41.82539
10		0.1	1.041	1.65697	45.39103
25		0.04	1.198	1.68366	48.26808
50		0.02	1.27	1.6959	49.6478
100		0.01	1.318	1.70406	50.58945
200		0.005	1.351	1.70967	51.24718

DISCUSSION OF RESULTS

The flood frequency analysis conducted on the Kafin Hausa River using 46 vears of annual maximum streamflow data (1976-2021) revealed that the Log Pearson Type III (LP3) distribution provided the best fit for the data. This finding is consistent with several other studies in similar hydrological contexts, particularly in semi-arid regions where flood events are influenced by extreme rainfall and variable catchment characteristics. For instance, studies in Nigeria (e.g., Idris, 2015; Odunuga and Raji, 2014) and other regions such as India (e.g., Islam and Sarkar, 2020) have also identified LP3 as a suitable distribution for flood frequency analysis, especially in regions with skewed hydrological data.

The predicted discharges for various return periods (2, 5, 10, 25, 50, 100, and 200 years) were found to be 33.11, 41.69, 45.70, 48.27, 49.65, 50.59, and 51.25 m³/s, respectively. These results are critical for flood risk management and the design of hydraulic structures in the Kafin Hausa River basin. The relatively low discharge values for shorter return

periods (e.g., 2 and 5 years) suggest that the River experiences moderate flood events frequently, while the higher discharge values for longer return periods (e.g., 100 and 200 years) indicate the potential for more severe flooding in extreme events. This information is vital for infrastructure planning, particularly for the design of bridges, culverts, and flood control measures that need to withstand extreme flood events.

The Generalized Extreme Value (GEV) distribution also performed well in the goodness-of-fit tests, ranking closely behind LP3. This is not surprising, as GEV is widely recognized for its flexibility in modeling extreme hydrological events. However, LP3 was ultimately selected due to its slightly better fit, as determined by the Least Sum of the Statistical Model Identification Criterion (LSSMIC). This finding aligns with studies such as those by Bhat et al. (2019) and Kumar and Jha (2024), which also found LP3 to be superior in flood frequency analysis in similar River basins.

The skewness coefficient (Cs = -1.4151) calculated for the Kafin Hausa River

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data indicates a negative skew, which is typical for flood data in semi-arid regions where extreme events are less frequent but can be severe. This skewness further justifies the use of LP3, as it is well-suited for modeling skewed hydrological data. The frequency factors (K) calculated for LP3 were consistent with those found in standard hydrology textbooks, further validating the methodology used in this study.

When compared to other studies in Nigeria and similar regions, the predicted discharges for the Kafin Hausa River are relatively moderate. For example, studies on the Hadejia River (Ibrahim et al., 2016) and the Niger River (Ibeje, 2020) reported higher discharge values for similar return periods, likely due to differences in catchment size, rainfall patterns, and land use. This highlights the importance of region-specific flood frequency analysis, as flood characteristics can vary significantly even within the same country.

LIMITATIONS

While the study provides valuable insights, it is important to acknowledge its limitations. The analysis assumes stationarity, meaning that the statistical properties of the streamflow data (e.g., mean, variance) do not change over time. However, climate change and land use changes can alter hydrological regimes, potentially leading to non-stationarity. Future studies should consider non-stationary flood frequency analysis to account for these changes. Additionally, the study relies on historical data from a single gauging station. Expanding the analysis to include data from multiple stations within the basin could provide a more comprehensive understanding of flood patterns.

CONCLUSION

This study successfully conducted a flood frequency analysis of the Kafin Hausa River using 46 years of annual maximum streamflow data (1976-2021). The Log Pearson Type III (LP3) distribution was identified as the best-fit model for the data, and it was used to predict flood discharges for return periods ranging from 2 to 200 years. The predicted discharges were found to be 33.11, 41.69, 45.70, 48.27, 49.65, 50.59, and 51.25 m³/s for 2, 5, 10, 25, 50, 100, and 200-year return periods, respectively. These results are critical

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for flood risk assessment and the design of hydraulic structures in the Kafin Hausa River basin.

The study highlights the importance of using region-specific flood frequency analysis, as flood characteristics can vary significantly depending on local hydrological and climatic conditions. The findings are consistent with other studies in Nigeria and similar regions, further validating the use of LP3 for flood frequency analysis in semi-arid environments.

RECOMMENDATIONS

- 1. The predicted flood discharges should be used as a basis for designing hydraulic structures such as bridges, culverts, and flood control measures in the Kafin Hausa River basin.
- Structures should be designed to withstand the 100-year or 200-year flood events to ensure long-term safety and resilience.
- The establishment of automated gauging stations at Kafin Hausa and other locations within the basin is recommended to provide continuous and detailed streamflow data.
- 4. Future studies should consider the potential impacts of climate change and land use changes on flood frequency. Nonstationary flood frequency analysis could provide more accurate predictions in a changing environment.
- Collaboration with neighboring regions and countries sharing similar hydrological characteristics could enhance data sharing and improve the accuracy of flood frequency analyses. This is particularly important for transboundary River basins.
- The findings of this study should be disseminated to local communities and stakeholders to raise awareness about flood risks and improve flood preparedness. Community-based flood management strategies should be developed to complement structural measures.

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