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Efficiency of Modified Mixed Gamma Distribution in Estimating Annual Maximum and Minimum Flows at Moniya Gauging Station, Nigeria

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Abstract: Reliable estimates of extreme flood flows are required for general flood risk management and planning. To assess the risk and nature of flood discharge, modified mixed-gamma distribution was applied to different plotting positions in taking care of shortfall in gamma distribution and how best it will estimate flood frequency at Moniya Gauging Station along Ona River. Goodness of fit, minimum absolute difference (MAD) and root mean square error (RMSE) between the observed and predicted flood flows were measured. Gamma distribution matched with Weibull plotting position which gave the highest coefficient of determination (R^2) of 0.9966; mixed gamma with California gave 0.9947 while modified mixed gamma with Weibull gave 0.9964 respectively. The MAD of 49.653, 3.123 and 20.922 at return periods of 50, 100, and 200-year obtained under the gamma when matched with Weibull, California and Weibull plotting positions respectively. California gave minimal error with the RMSE of 92.85 for gamma with some information lost, correcting for error incurred, Weibull gave minimal errors of 159.20 and 93.91 for mixed gamma and modified mixed gamma distributions, respectively. Hence, we conclude that modified mixed gamma distribution with Weibull plotting position is the most suitable for prediction at the gauging station.

Key words: Hydrologic modelling, modified mixed gamma, plotting position, statistical analysis, stream flow.

Introduction

Hydrological structures are occasionally impacted by extreme events such as rainfall, storms, floods and droughts. Frequency analysis of hydrological data according to Ojha et al. (2008) aimed at relating the magnitude of extreme events to their frequency of occurrence with probability distributions. Flood damage relief measures were required by increased runoff due to rapid urbanization of the catchment area, coupled with inadequate runoff data along the river course (Adegbola and Jolayemi, 2012). Estimation of the flooding potential at a site is needed for the design of river engineering works and urban planning (Topaloğlu, 2005) in order to reduce the natural disasters caused by flood including loss of life, injury, damage to agricultural lands, and major property losses among others. A technique of decreasing flood damages and economic losses is flood frequency analysis (Ewemoje and Ewemooje, 2011). In real-time flood forecasting systems for civil protection activities, the model has to be reliable for use in flood estimation with low computational effort and high speed (Brocca et al., 2011) but there are a number of difficulties regarding the overall computational and data demand. This may get more difficult as the number of studied basins increases (Ding et al., 2016).

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In hydrological analyses, the annual maximum flood flow is carefully measured to be a random variable and statistical methods are employed for the analysis of random variables. The flood frequency analysis is to infer the probability of exceedance of all possible discharge values from observed discharge values. This is accomplished by selecting a statistical model that approximately represents the relationship between discharge magnitude and exceedance probability for the target area/site. The parameters of the models are estimated from sampled data using estimated parameters. The probability of exceedance can be predicted for a particular magnitude or the magnitude with specified exceedance probability. Reliable estimates of extreme flood events are required for the design and operation of vital infrastructure and for more general flood risk management and planning (Ehiorobo and Izinyon, 2013).

Many probability distribution functions have been used to model occurrences such as rainfall, stream flow, precipitation, flood and so on which are considered to be either significant or non-significant. These include: Normal, Log-normal, EV- I (Extreme value type - 1), Pearson Type III (Gamma) and Log Pearson Type III among others. Maposa et al. (2015) compared ten candidate distributions: Generalised Gamma (GG), two-parameter Gamma, three-parameter Gamma, two-parameter lognormal, three-parameter lognormal, log-Pearson Type 3 (LP3), Generalised Extreme Value (GEV), two-parameter Weibull, three-parameter Weibull, and Gumbel distributions in modelling the annual maximum daily flood heights in the lower Limpopo River Basin, Mozambique. Application of some of these distributions are also extended to other areas like road traffic fatalities (Ewemooje, 2014), study on bus motor failure (Mudholkar et al., 1995) and so on.

The gamma distribution has been widely used to model rainfall due to its simplicity since it has only two parameters: shape and scale. However, gamma distribution is limited in its usage as it is only suitable for positive data while mixed-gamma distribution provides a way out by accommodating both zero and positive stream-flow and flood data. Thom (1968) used mixed gamma distribution in precipitation data analysis where two general physical systems operate: one producing precipitation while the other does not. Rosenberg et al. (2004) use mixed-gamma distribution associated with Laguerre polynomials while Piantadosi et al. (2009) also use the mixed-gamma distribution to generate synthetic rainfall totals on various timescale including daily, monthly and yearly. In this study, we develop and apply the modified mixed-gamma probability distribution to different plotting positions in order to correct the shortfall in gamma distribution and observe how best it will estimate flood frequency at Moniya Gauging Station along Ona River. In addition, compare it with gamma and mixed-gamma probability distributions.

Materials and Methods

River basins according to Oke et al. (2013) has been defined as the geographic area contained within the watershed limits of a system of streams and rivers converging toward the same terminus, generally the sea or sometimes an inland water body. In Nigeria, Ogun-Osun River Basin Development Authority (OORBDA) is charged with the responsibility of the development and management of the water resources in its area of coverage of Osun, Oyo, Ogun and Lagos States. The coverage of OORBDA falls within latitudes 6°30′-8°20′ N and longitudes 3°23′-5°10′ E, and it is drained by two main rivers, Ogun and Osun, with a number of tributaries and smaller rivers namely: Sasa, Ona, Ibu, Ofiki and Yewa.

Many rivers in Sub-Saharan Africa have low flow especially in dry season, a situation that gives rise to serious concern for long-term domestic, animal and irrigation supplies in the region (Rangeley et al., 1994). Streams that usually have flows in rainy seasons and reduced or no flows during dry seasons are usually referred to as ephemeral or intermittent streams or rivers. Wilson (1990) observed that groundwater table lies above the bed of such stream during the wet season but drops below the bed during the dry season. Flow in such rivers is derived principally from surface runoff in dry season, but during wet season, they receive some contribution from ground water.

Methodology

A total of 504 monthly rainfall data from January 1973 to December 2014 (42 years) was collected from the Moniya hydrometric gauging station along Ona river managed by Ogun-Osun River Basin Development Authority (OORBDA). The collected data was subjected to three probability distributions and plotting positions discussed below to determine the most efficient probability distribution to model for the gauging station.

Flood Frequency Analysis

Frequency analysis is used in estimating the relationship between an event x and the return period, T, of that event. In annual maximum rainfall data, the return period T is related to the exceedance probability of x, $P_X(X \geq x)$, using the relation:

$$P_X(X \geq x) = \frac{1}{T} \quad (1)$$

then the cumulative distribution function of x, $P_X(X < x)$ is related to T by the relation:

$$P_X(X < x) = F = 1 - \frac{1}{T} \quad (2)$$

which is the same as the non-exceedance probability, F, as described by Yoo et al. (2005).

The non-exceedance probability, F, of a mixed distribution has a different relation with the return period, T, which can be expressed by considering the probability of rainfall occurrence λ.

$$F_{\text{mixed}} = \left(1 - \frac{1}{T}\right) - (1 - \lambda) = \lambda - \frac{1}{T} \quad (3)$$

Equation (3) is then transformed into that of a continuous distribution using the following relation:

$$P_{Mixed}(X \leq x) = F_{Mixed} = 1 - \frac{1}{\lambda T} \quad (4)$$

Hence, the probability of exceedance of x, $P_{Mixed}(X > x)$, for mixed distribution is given by:

$$P_{Mixed}(X > x) = \frac{1}{\lambda T} \quad (5)$$

Gamma Distribution

The probability density function of a three-parameter gamma distribution, also known as Pearson Type III distribution, is given as:

$$f(x) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)}(x-\gamma)^{\alpha-1}e^{-(x-\gamma)/\beta}, \quad x \geq \gamma \quad (6)$$

The mean, variance and coefficient of skewness of the distribution are given by $\mu_x = \gamma + \alpha\beta, \sigma_x^2 = \alpha$, and $g_x = 2/\sqrt{\alpha}$ respectively. Frequency factor, K_T, depends on both return period, T, and coefficient of skewness, g_x. This can be estimated using the relation (Chin, 2006).

$$K_T = \frac{1}{3k}\left[\left\{(x'_T - k)k + 1\right\}^3 - 1\right] \quad ...(7)$$

where x'_T is the standard normal variate relating to the return period, T and k is calculated from the coefficient of skewness by:

$$k = \frac{g_x}{6} \quad (8)$$

The predicted floods X_T, is given by:

$$X_T = \mu_x + K_T.\sigma_x \quad (9)$$

where μ_x, K_T and σ_x are as previously defined.

Mixed Gamma Distribution

According to Yoo et al. (2005) a mixed distribution can be explained as: let X be a random variable at a location, then X should be zero for the dry period and its probability can be written as:

$$P(X = 0) = 1 - \lambda \quad (10)$$

where λ represents the probability of wet days. However, under wet conditions (that is, during the wet period), X follows a continuous distribution, whose probability of being smaller than or equal to a rainfall depth x can be expressed by use of a cumulative probability distribution function $F(x)$. Hence, the distribution function of considering both the wet and dry periods is expressed by the mixed distribution (Kedem et al., 1990) as:

$$\varphi(x) = (1 - \lambda)G(x) + \lambda F(x) \quad (11)$$

where $\varphi(x)$ is the distribution function of X considering both the wet and dry periods, $G(x)$, is defined as a step function as follows:

$$G(x) = 0, \text{ if } x = 0$$
$$G(x) = 1, \text{ if } x > 0 \quad (12)$$

Therefore, $F(x)$ or the corresponding $f(x)$ is the continuous part of rainfall (wet period) while $G(x)$ is the discrete part of rainfall (dry period). The gamma distribution procedure is then followed using equations (6), (7), (8) and (9) in predicting flood X_T and all parameters remain as earlier defined.

Modified Mixed Gamma Distribution

Let X be a random variable at a location, then X should be zero for the dry period and its probability as written in equation (10); also, let n be the sample size of the maximum rainfall. In mixed gamma distribution, it was observed that as the rank, R, increases (i.e. $R \to n$), the probability of exceedance increases to an extent that it becomes greater than one (1) which is a violation of the rules guiding the theory of probability. Hence, we eliminate all samples where the probability of exceedance is greater than one which cause reduction in the entire sample size (i.e. $m = n - k$), where m is the new sample size while k is the sample size of all period with probability of exceedance greater than one. Therefore, the continuous distribution function in equation (4) expressed by the modified mixed distribution is:

$$P_{CM}(X \le x) = F_{CM} = \int_0^m f(x)dx, \quad m < n \qquad (13)$$

The mixed gamma distribution procedure is then followed using equations (10), (11), and (12) in predicting flood X_T and all parameters remain as earlier defined.

Results and Discussions

Results

The time plot of maximum or peak annual flows and mean annual flows of 42 years is as shown in the annual hydrograph (see Figure 1). Highest discharge of 2167.9 m^3/s was observed in year 2002 with sharp decline to 374 m^3/s in year 2003. The minimum peak flow for Ona River at Moniya gauging station was 333.6 m^3/s in the year 2006. Minimum and maximum mean annual flows were 157.9 and 889.7 m^3/s for years 2006 and 1999 respectively. The difference in flow magnitudes can be attributed to intermittent ephemeral nature of the stream flow: usually dry up or have reduced flow in the peak dry season or years with reduced rainfall resulting in draughts. The overall average maximum annual flow is 1219.33 m^3/s with standard deviation of 507.59 m^3/s over the period considered in the study.

Gamma Distribution

In Figures 2(i-iii), the polynomial regression model of the maximum annual flow and probability of exceedance using Gamma distribution yields R^2 = 0.9863 for observed values. However, predicted values with Hazen plotting position gives $y = 4243.9x^3 - 7123.2x^2 + 4962.4x + 46.842$ (R^2 = 0.9926); Weibull plotting position gives $y = 3624.5x^3 - 6094.1x^2 + 4462x + 112.36$ (R^2 = 0.9966) and California plotting position gives $y = 4114.5x^3 - 6729.2x^2 + 4677.2x + 97.296$ (R^2 = 0.9949). The Root Mean Square Error (RMSE) for Hazen, Weibull and California are 101.72, 93.19 and 92.85 respectively. The peak annual flow using Hazen with return periods of 50, 100 and 200 years are 1733.25, 1753.90 and 1793.96 with absolute differences of 59.86, 10.97 and 24.25 respectively. Weibull with return periods of 50, 100 and 200 years are 1723.05, 1748.29 and 1790.63 with absolute differences of 49.65, 16.58 and 20.92, respectively while California are 1748.29, 1761.75 and 1798.32 with absolute differences of 74.89, 3.12 and 28.61, respectively.

Mixed Gamma Distribution

The regression model for the peak annual flow and the probability of exceedance using mixed gamma distribution (Figures 3i-iii) for observed values yield varying coefficient of determination: Hazen R^2 = 0.9776, Weibull gives R^2 = 0.9788 and California gives R^2 = 0.9762. For predicted values, Hazen gives y =

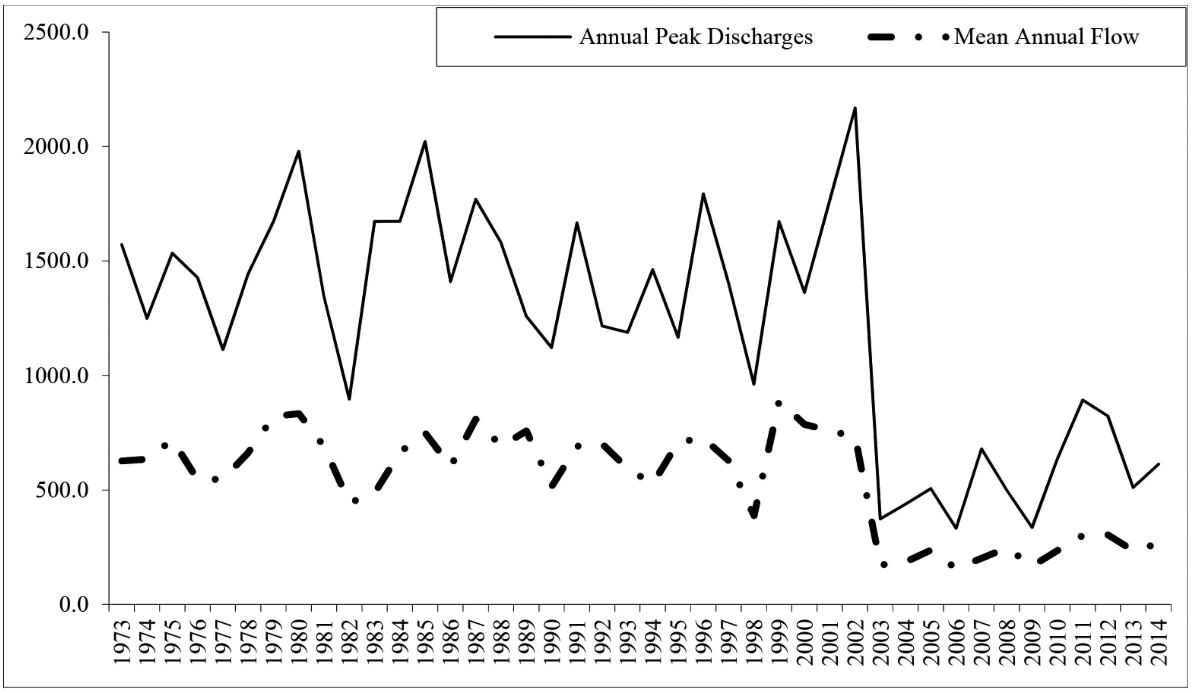


Figure 1: Annual flows of Ona River at Moniya Gauging Station, 1973 to 2014.

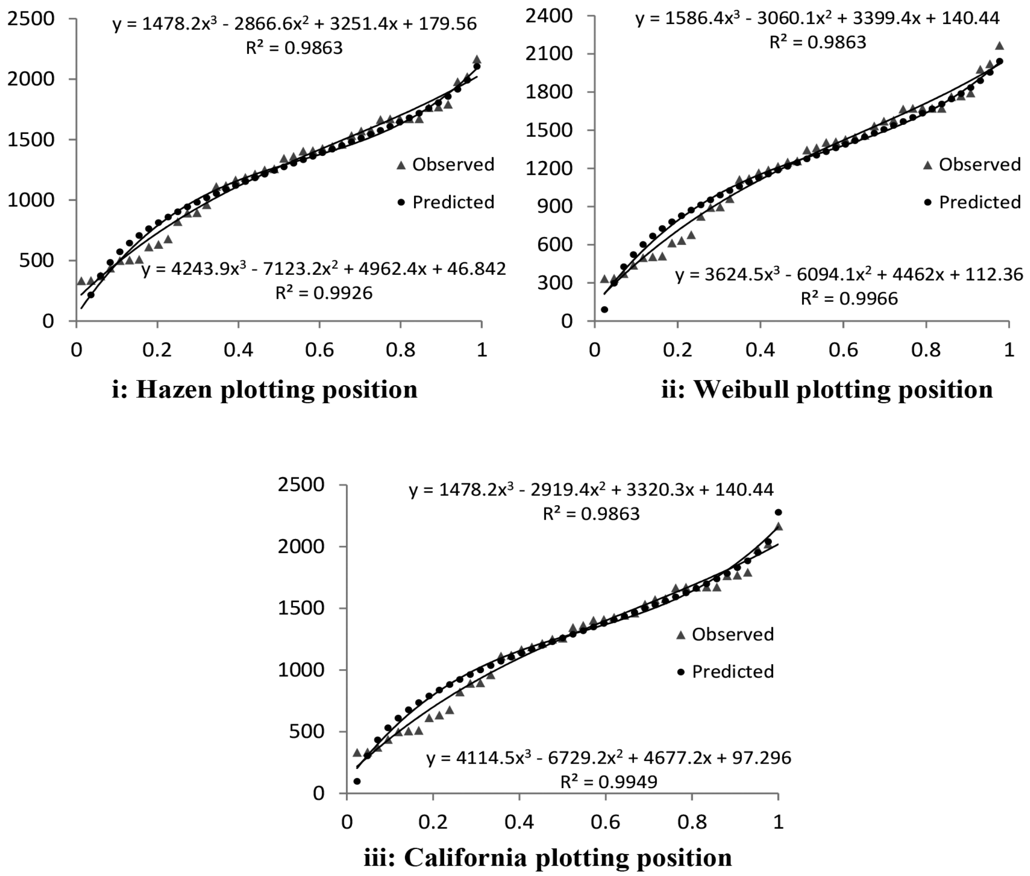


Figure 2: Plot of gamma distribution in relation with the three plotting positions.

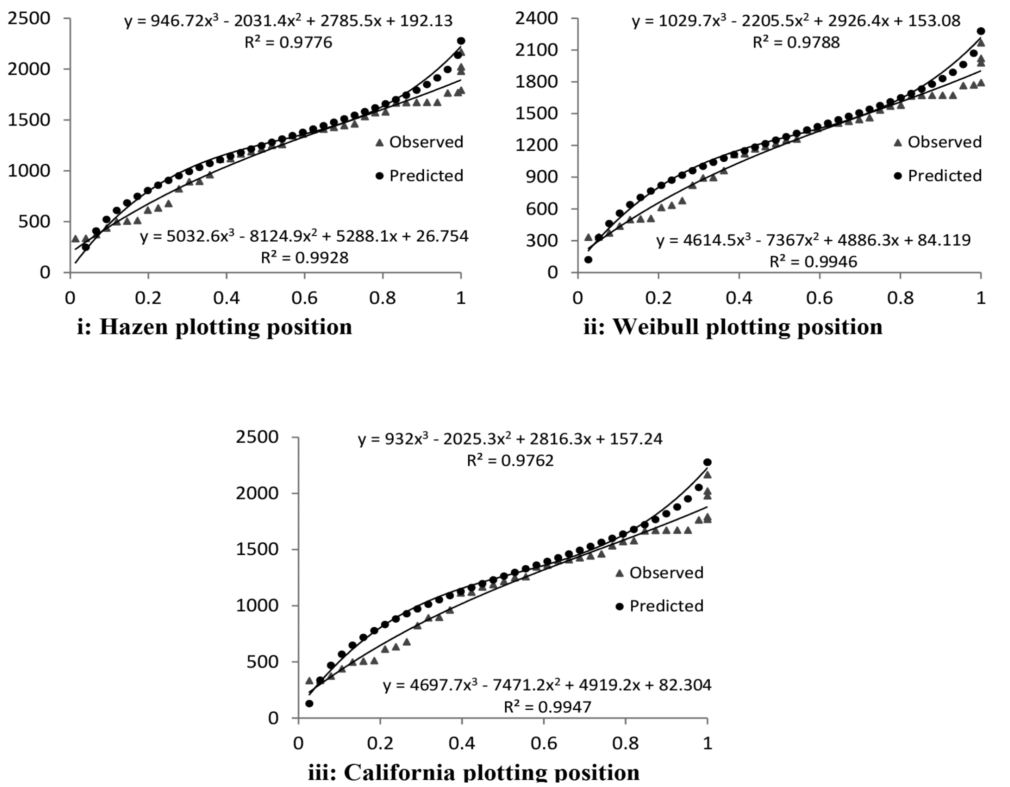


Figure 3: Plot of mixed gamma distribution in relation with three plotting positions.

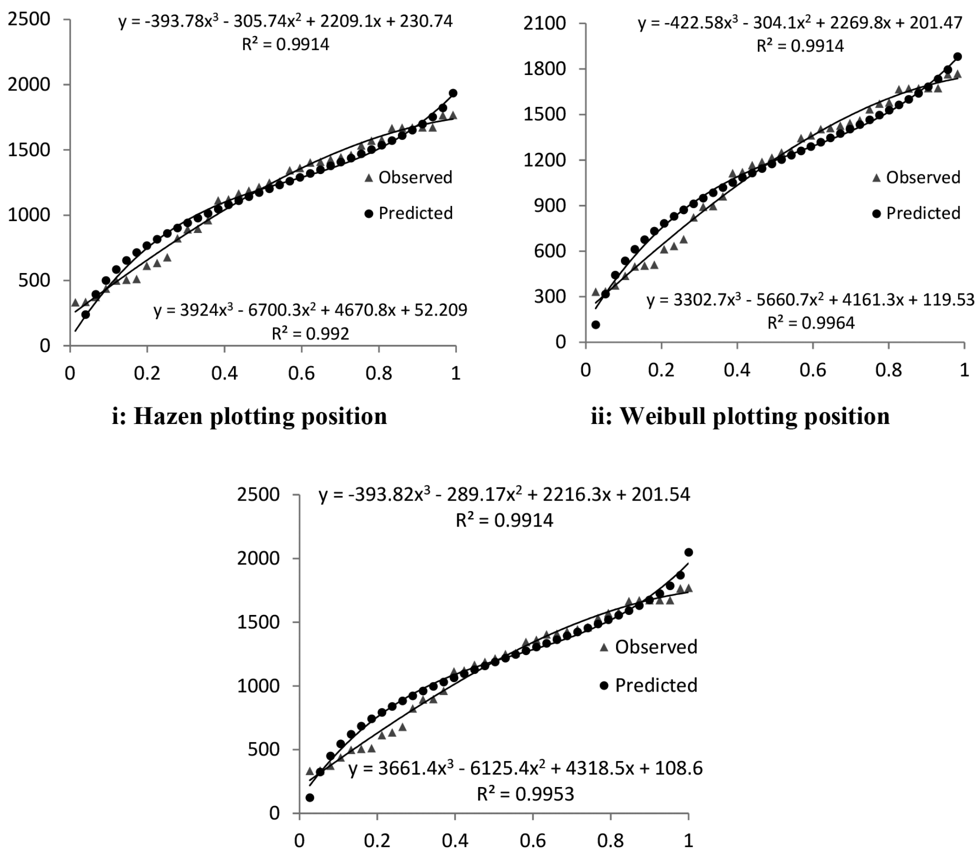
$5032.6x^3 - 8124.9x^2 + 5288.1x + 26.754$ ($R^2 = 0.9928$); Weibull gives $y = 4614.5x^3 - 7367x^2 + 4886.3x + 84.119$ ($R^2 = 0.9946$) and California gives $y = 4697.7x^3 - 7471.2x^2 + 4919.2x + 82.304$ ($R^2 = 0.9947$). Root Mean Square Error (RMSE) for Hazen, Weibull and California plotting positions are 169.30, 159.20 and 183.40 respectively. Peak annual flow using Hazen with return periods of 50, 100 and 200 years are 1939.24, 1981.40 and 2087.48; these are generated with absolute differences of 265.85, 216.53 and 317.77 respectively. The maximum annual flow using Weibull with return periods of 50, 100 and 200 years are 1920.07, 1969.43 and 2076.46 with absolute differences of 246.67, 204.56 and 306.75, respectively. Also, the maximum annual flow using California with return periods of 50, 100 and 200 years are 1969.43, 1998.98 and 2103.06 with absolute differences of 296.03, 234.11 and 333.35, respectively.

Modified Mixed Gamma Distribution

The polynomial regression model for the annual flow and the probability of exceedance using modified mixed gamma distribution on observed values yield $R^2 = 0.9914$ while predicted values with Hazen gives $y = 3924x^3 - 6700.3x^2 + 4670.8x + 52.209$ ($R^2 = 0.992$); Weibull gives $y = 3302.7x^3 - 5660.7x^2 + 4161.3x + 119.53$ ($R^2 = 0.9964$) and California gives $y = 3661.4x^3 - 6125.4x^2 + 4318.5x + 108.6$ ($R^2 = 0.9953$). The RMSE for Hazen, Weibull and California are 104.34, 93.91 and 103.22, respectively. The peak annual flow using Hazen with return periods of 50, 100 and 200 years are 1775.32, 1810.27 and 1897.13 with absolute differences of 101.92, 45.40 and 127.42 respectively. The peak flow using Weibull plotting position are 1759.34, 1800.37 and 1888.18 with absolute differences of 85.95, 35.50 and 118.47, respectively while California are 1800.37, 1824.78 and 1909.75 with absolute differences of 126.97, 59.91 and 140.04, respectively (See Figures 4(i-iii)).

Discussion

From Figures 2-4, it was observed that the gamma matched with Weibull gave the highest coefficient of determination (R^2) of 0.9966 when compared with Hazen and California with 0.9926 and 0.9949 respectively which is in agreement with Hann (1994).



i: Hazen plotting position

ii: Weibull plotting position

iii: California plotting position

Figure 4: Modified mixed gamma distribution in relation with three plotting positions.

Table 1: Relationship between the observed and the predicted flows along Ona River at Moniya gauging station

		Coefficient of determination (R^2)			*Root Mean Squared Errors (RMSE)*			*Return periods (T)*	*Predicted flows*			*Absolute differences*		
Plotting position		*Hazen*	*Weibull*	*California*	*Hazen*	*Weibull*	*California*		*Hazen*	*Weibull*	*California*	*Hazen*	*Weibull*	*California*
Probability distribution	Gamma	0.9926	0.9966	0.9949	101.72	93.19	92.85	**50**	1733.252	1723.049	1748.291	59.856	49.653	74.895
								100	1753.897	1748.291	1761.745	10.971	16.577	3.123
								200	1793.962	1790.632	1798.324	24.251	20.922	28.614
	Mixed-Gamma	0.9928	0.9946	0.9947	169.30	159.20	183.40	**50**	1939.243	1920.069	1969.426	265.847	246.673	296.030
								100	1981.398	1969.426	1998.978	216.531	204.558	234.110
								200	2087.482	2076.455	2103.055	317.772	306.745	333.345
	Modified Mixed-Gamma	0.992	0.9964	0.9953	104.34	93.91	103.22	**50**	1775.317	1759.341	1800.367	101.921	85.945	126.971
								100	1810.270	1800.367	1824.775	45.402	35.500	59.907
								200	1897.133	1888.180	1909.745	127.423	118.470	140.035

However, for the mixed gamma and modified mixed gamma distributions; California with 0.9947 and Weibull with 0.9964 respectively.

Merging of the plotting positions and probability distributions shows that California gave minimal error with the RMSE of 92.85 for gamma while Weibull gave the minimal errors of 159.20 and 93.91 for mixed gamma and modified mixed gamma respectively. This shows that using California or Weibull to forecast will statistically make the predicted values not to be far from the observed flows for Ona River at Moniya Gauging Station for period under consideration.

In Table 1, minimum absolute differences of 49.653, 3.123 and 20.922 at return periods of 50-year, 100-year and 200-year are obtained under the gamma (Pearson Type III) distribution when merged with Weibull, California and Weibull respectively. This finding is in agreement with the work of Ewemoje and Ewemooje (2011) which reported that Log-Pearson Type III (gamma) probability distribution merged with Weibull plotting position gives the best fit. The absolute difference implies that the magnitudes of error inherent between observed and predicted maximum flows at the different return periods are relatively minimal. Therefore, gamma with the least absolute differences for all the plotting positions is seen as the best distribution among the three for Ona river at Moniya Gauging Station but this with hidden errors of discarding rainfall data for days/weeks/months of zero or no rainfall, thereby reducing the sample size.

However, use of mixed gamma resulted in more errors than expected as the RMSE increased from 101.72 (in gamma) to as high as 183.40. However, it also gave R^2 of 0.9947 that is very close to that of gamma. Therefore, the need to modify/improve on the mixed gamma to obtain minimal error lower or very close to that of gamma while including all sample points in the estimation of all parameters. With this in mind, we modified the mixed gamma accordingly and obtained R^2 closer to that of gamma for Hazen and Weibull as 0.992 and 0.9964 respectively while a higher R^2 of 0.9953 was obtained for California when compared to the R^2 of 0.9949 due to gamma distribution. Also, reduced RMSE 104.34, 93.91 and 103.22 were obtained in modified mixed gamma distribution for Hazen, Weibull and California, respectively against RMSE 169.3, 159.2 and 183.4 obtained in mixed gamma distribution.

Conclusion

The errors were reduced with the use of modified mixed gamma compared to that of mixed gamma distribution. The root mean square error due to modified mixed gamma with the use of Hazen, Weibull and California plotting positions were noted to be very close to the root mean square error due to gamma distribution where some information was lost. Furthermore, information lost with the use of gamma distribution was corrected with the use of modified mixed gamma distribution and errors minimized. We, therefore, conclude that modified mixed gamma distribution with Weibull plotting position is the most suitable for prediction of flows along Ona River at Moniya gauging station.

References

Adegbola, A.A. and J.K. Jolayemi (2012). Historical rainfall-runoff modeling of river Ogunpa, Ibadan, Nigeria. *Indian Journal of Science and Technology*, **5(5):** 2725-2728.

Brocca, L., Melone, F. and T. Moramarco (2011). Distributed rainfall-runoff modelling for flood frequency estimation and flood forecasting. *Hydrological Processes*, **25:** 2801-2813. DOI: 10.1002/hyp.8042

Chin, D.A. (2006). Water Resources Engineering (2nd ed.). Pearson Prentice Hall, Upper Saddle River, New Jersey.

Ding, J., Wallner, M., Müller, H. and U. Haberlandt (2016). Estimation of instantaneous peak flows from maximum mean daily flows using the HBV hydrological model. *Hydrological Processes*, **30:** 1431-1448. DOI: 10.1002/hyp.10725

Ehiorobo, J.O. and O.C. Izinyon (2013). Flood Frequency Analysis at Oshun River in Asejire Dam Site, Nigeria. *Journal of Earth Science and Engineering*, **3:** 292-300.

Ewemoje, T.A. and O.S. Ewemooje (2011). Best distribution and plotting positions of daily maximum flood estimation at Ona River in Ogun-Oshun river basin, Nigeria. *Agric. Eng. Int: CIGR Journal*, **13(3):** 1-11.

Ewemooje, O.S. (2014). Modelling Road Traffic Fatalities in Nigeria with Weibull Distribution. *Advances in Agriculture, Sciences and Engineering Research*, **4(4):** 1595-1600.

Haan, C.T. (1994). Statistical Methods in Hydrology. Iowa State University Press. Ames.

Kedem, B., Chiu, L.S. and Z. Karni (1990). An analysis of the threshold method for measuring area-average rainfall. *Journal of Applied Meteorology*, **29:** 3-20.

Maposa, D., Cochran, J.J. and M. Lesaoana (2014). Investigating the goodness-of-fit of ten candidate distributions and estimating high quantiles of extreme floods in the lower Limpopo River Basin, Mozambique. *Journal of Statistics and Management Systems*, **17(3):** 265-283. DOI: 10.1080/09720510.2014.927602

Mudholkar, G.S., Srivastava, D.K. and M. Freimer (1995).

The exponentiated Weibull family: A reanalysis of the bus-motor-failure data. *Technometrics*, **37(4):** 436-445.

Ojha, G.S.P., Bernisson, R. and P. Bhunya (2008). Engineering Hydrology. Oxford University Press, New Delhi.

Oke, A.O., Sangodoyin, A.Y., Ogedengbe, K. and T. Omodele (2013). Mapping of River Water Quality using Inverse Weighted Interpolation in Ogun-Oshun River Basin, Nigeria. *Landscape & Environment*, **7(2):** 48-62.

Piantadosi, J., Boland, J.W. and P.G. Howlett (2009). Simulation of rainfall totals on various time scales – Daily, Monthly and Yearly. *Environmental Modeling and Assessment*, **14(4):** 431-438.

Rangeley, R., Thiam, B.M., Andersen, R.A. and C.A. Lyle (1994). International River Basin Organizations in Sub-Saharan Africa. World Bank Technical Paper Number 250, Africa Technical Department Series, The World Bank, Washington, D.C.

Rosenberg, K., Boland, J.W. and P.G. Howlett (2004). Simulation of monthly rainfall totals. *ANZIAM Journal*, **46(E):** E85-E104.

Thom, H.C.S. (1968). Approximate Convolution of the Gamma and Mixed Gamma Distributions. *Monthly Weather Review*, **96(12):** 883-886.

Topaloğlu, F. (2005). Regional Flood Frequency Analysis of the Basins of the East Mediterranean Region. *Turkey Journal of Agric*, **29:** 287-295.

Wilson, E.M. (1990). Engineering Hydrology (4th ed.). Macmillan Press Ltd., London.

Yoo, C., Jung, K.-S. and T.-W. Kim (2005). Rainfall frequency analysis using a mixed Gamma distribution: Evaluation of the global warming effect on daily rainfall. *Hydrological Processes*, **19:** 3851-3861. DOI: 10.1002/hyp.5985

Calendar of Events

4th International Conference on Water Pollution and Treatment (ICWPT 2019)
16th to 18th July 2019
Rome, Italy
Website: http://www.icwpt.net/
Contact person: Ms. Emma Chen
Organized by: ICWPT

5th International Congress on Water, Waste and Energy Management, WWEM-19
22nd to 24th July 2019
Paris, France
Website: https://waterwaste-19.com/
Contact person: Javier Ladera
Organized by: Sciknowledge European Conferences

International Conference on Water Conservation & Environmental Management (WC2EM)
26th to 28th July 2019
Ho Chi Minh, Vietnam
Website: https://inwascon.org.my/wc2em/
Contact person: Alhakim
Organized by: INWASCON

International Conference on Water, Informatics, Sustainability, and Environment (iWISE2019)
7th to 9th August 2019
Ottawa, Ontario, Canada
Website: http://www.iwiseconference.com
Contact person: W.A. Eldin
Organized by: Ottawa Assembly of Knowledge

5th International Conference on Advances in Environment Research (ICAER 2019)
13th to 16th August 2019
Singapore
Website: http://www.icaer.org
Contact person: Ms.Emma Chen
Organized by: ICAER

22nd International Water Technology Conference
12th and 13th September 2019
Ismailia, Egypt
Website: http://iwtc2019.website2.me
Contact person: Walaa Tarek
Organized by: IWTA

6th International Conference on Water, Energy and Environmental Research (ICWER2019)
22nd to 24th September 2019
Abuja, Nigeria
Website:http://www.unimaid.edu.ng/Circulars/6th%20International%20Conference%20on%20%20Water,%20Energy%20and%20Environmental%20Research,%20Abuja-Nigeria.pdf
Contact person: Professor J.A. Opara
Organized by: International Association for Teaching and Learning and University of Maiduguri