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Full Length Research Article

INTENSITY, DURATION AND FREQUENCY OF RAINSTORMS IN LOKOJA

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ABSTRACT
This study analyzed the Intensity, duration and frequency (IDF) of rainstorms in Lokoja. Daily rainfall data were collected from Nigerian Meteorological Agency (NiMET). These data were for fifty-five years (1955-2010).The Weibull's equation was used to plot the return periods of the IDF. The data were fitted to gamma distribution, while the IDF curves were generated using the Gumbel's distribution. Furthermore, a model expressing the relationship among intensity, duration and frequency of rainstorms for Lokoja was developed. Results showed that the highest annual rainfall in Lokoja in the last 35 years occurred in 1999 with a depth of 1767.1mm with a return period of 36 years while the lowest rainfall occurred in 1982 with an amount of 804.5mm and a return period of one year. The IDF model showed various rainstorm occurrences in Lokoja with their intensities. The highest rainfall intensities are those of relatively low duration (0.2 to 0.7hrs), the medium intensities for 1 to 3hrs durations and the lowest intensities for 6 to 24hrs durations). The highest intensity was that of 0.2 hour (226mm) with a return period of 100 years. The lowest intensity for 0.2 hour was 66.1mm with a return period of 1 year. The IDF curves also confirmed that rainfall intensity in Lokoja decreases with increasing time interval. This study therefore, will be useful in the design of hydrologic facilities like dams and drainage channels.

Keywords: Intensity, Duration, Frequency, Rainstorms and Return Period

INTRODUCTION

Rainfall worldwide has certain characteristics where it occurs. These characteristics include amount, seasonality, intensity, duration and frequency. In Nigeria, these characteristics have been studied by several researchers (Walsh and Lawler, 1981 Ayoade, 1970; Odekunle, 2006; Ifabiyi and Ojoye, 2013). The application of some of these characteristics to everyday situations and activities have also been carried out by others (Ayeni and Oni, 2012; Antigba, 2012; Ugbong, 2000; Leton, 2005; Nwadike, 2008). Also, studies concerning the relationship amongst these characteristics (especially Intensity, Duration and frequency of rainstorms) and their effects on human activities and situations have received much attention in the southern region of Nigeria as well as cities there. However, not much of such studies have been done in the north- central region of Nigeria especially as it concerns Lokoja (Nwaogazie and Duru, 2002; Nwoke and Okoro, 2012; Oyebande, 1980 & 1982; Akpan and Okoro, 2013; Antigba and Ogarekpe, 2013). This is despite the well-known fact that the city is prone to the occurrence of floods due to its topography (Fig. 1 and Areola, 2004) This study intends to fill this gap and look at the relationship amongst intensity, duration and frequency of rainstorms in Lokoja. This relationship is commonly determined through the statistical analysis of data from weather /meteorological stations. This is important because its study (IDF) can be used not only for erosive study, but can also be used for planning and designing of water resource projects (El-Sayed, 2011) as well as water engineering control structures. This becomes imperative as a result of the recent flood experienced in Lokoja and its environment. This is despite the fact that these floods cannot be entirely attributed to rainfall alone in the study area. Other attributes of the study area such as the soil and topography as well as water from the upland areas need to be taken into consideration as earlier mentioned above.

Lokoja the study area is a medium-size town located in North-Central Nigeria. It is the capital of Kogi state and it is located between Lat. 7^0 45'N- 7^0 51'N and Long. 6^0 41'E - 6^0 46'E. It is a settlement located at the confluence of Rivers Niger and Benue in Nigeria (Fig. 1). The earliest settlers in Lokoja were the Bassa-Nges and Oworos. The Bassa-Nges settled in 1760 while the Oworos came in 1831 (Akamisoko, 2002) with the missionaries arriving later. The other tribes that later settled in Lokoja include the several Nupe groups such as Kakanda, Kupa, Ganagana and Egan. Since attaining its present metropolitan status from pre-independence days, it is now home to many people from several Nigerian ethnic groups that include Igala, Hausa, Egbura, Yoruba, Igbo, Tiv and Idoma, just to mention but few. The Yorubas have been a dominant group since the days when the town was in former Kwara state while the Igalas also became a dominant group after the creation of Kogi state in 1991 and the attendant immigration into Lokoja. It is therefore a cosmopolitan town with an estimated population of over 127,139 (Lokoja Masterplan 2009).

The climate of Lokoja and its environs falls into koppen-Aw, this means it is the warm continental type (Olatunde and Ukoeje, 2016). Rainfall onset is around March/April while cessation is around October/November, with a short break in August. The average annual temperature rarely falls below 30.7 ^{0} C with February and March being the hottest months (Ifatimehin, Ishaya and Ujoh, 2010), while relative humidity is about 30% (dry season) and 70% (wet season) (Olivera *et al.*, 1995). The average daily wind speed is about 89.9 km/hr or about 3.0 to 4.6 Knots in the months of June/July and 1.5 to 3.7 Knots for December/January. The prevailing direction of wind for the months of June/July and December/January are South to South Westerly and North Easterly respectively. The average daily vapour pressure is about 26 Hpa (Audu, 2012). The soils are generally characterized by a sandy texture overlying a weakly structured clay accumulation (Atoyebi, 2013). The flood plains (of the Rivers Niger and Benue valleys) in Lokoja are made up of hydromorphic soils that contain mixture of coarse alluvial and colluvial deposits (Areola, 2004). The alluvial soils along the valleys of the rivers are sandy, while the adjoining laterite soils are deeply weathered grey or reddish in colour, sticky and permeable (Luca, 2012). The main vegetation type in Lokoja is Guinea or Parkland savannah with tall grasses and some trees. These are green in the rainy season with fresh leaves and tall grasses, but the land is open during the dry season, showing charred trees and the remains of burnt grasses (Luca, 2012).

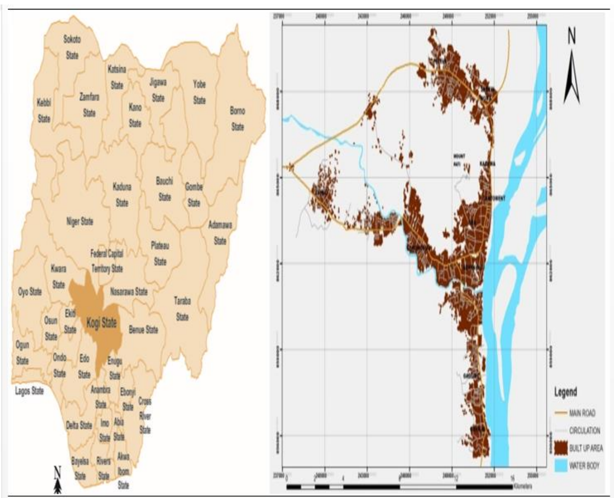

Fig. 1: Kogi State in the context of Nigeria and Lokoja showing built up areas and adjacent rivers
Source: Alaci, 2015

DATA AND METHOD

Daily rainfall data of Lokoja were used for this study. The rainstorms data were for hours of 0.2, 0.4, 0.7, 1, 2, 3, 6, 12, and 24 from 1955 to 2010. The data were sourced from NiMET (Nigeria Meteorological Agency). The period that the data covered was chosen because of consistency and the need to make use of up to date data as much as possible, this with a view to take care of recent changes in climate.

For the construction of an IDF curve, the same numbers (n) of years were used for all durations, from 0.2 to 24 hours. Ideally, the value of the Means and Standard deviations should decrease with increasing duration, however, where this is not true the data is not homogenous. When rainfall data are available, IDF curves can be developed through frequency analysis.

In order to carryout analysis, the data were sorted out from the largest to smallest and values that fall below the lower limits of falls were removed. The lower limits of falls for 0.2, 0.4, 0.7, 1, 2, 3, 6, 12, and 24 hours were 12.7mm, 15.2mm, 20.3mm, 25.4mm, 25.4mm, 25.4mm, 30.48mm, 38.1mm and 38.1mm respectively (NiMET,2015).

The rainfall depth was converted into intensity using the formula below;

$i = \frac{d}{t}$ .... (1)

Where:
i= rainfall intensity,
d = the rainfall depth and,
t = rainfall duration.

The values were then ranked in decreasing order with the highest having the value of 1 in the ranked order.

The return periods T of the ranked values were then calculated using the Wiebull's formula (Wiebull, 1939) as seen in equation (2)

$T = \frac{n+1}{m}$ .... (2)

Where;
T = the return period in years;
n = the total number of the values; and
m = the rank value of each rainfall intensity

The probability was obtained using the following relationship:

$P = \frac{1}{T}$ .... (3)

Where:
P = probability and
T is the return period (recurrence interval).

After the rainfall intensity data mean ($\overline{X}$) and standard deviation(S) were derived. The rainfall intensity was then regressed against duration for each year using Hydro CAD software to obtain the K_T being the frequency factor for the return period. The K_T was then computed for corresponding return periods using Gumbel's distribution formula as shown below:

$K_T =$
$\frac{\sqrt{6}}{\pi}\{0.5772 + \mathrm{In}[\mathrm{In}\left(\frac{T}{T-1}\right)]\}$ .... (4)

Where T is return period.

Rainfall intensities were calculated for corresponding return periods.

$X_T = \overline{X} + K_T S$ .... (5)

Where:
K_T = the rainfall intensities for each return period,
S = the standard deviation of rainfall intensities,
$\overline{X}$ = the mean rainfall intensities,
X_T = the rainfall intensity for a given return period.

RESULT AND DISCUSSIONS

The mean and standard deviation of the data decreased with increasing time that is the value of the mean and standard deviation for 0.2hour was greater than that of 0.4hours, 0.7hours and so on, 24hours had the least values (Table 1). This indicated that rainfall event decreases with longer duration and that the data was homogenous (Table 1).

Table 1: Mean, Standard Deviation, Skewness and Kurtosis

	0.2H	0.4H	0.7H	1H	2H	3H	6H	12H	24H
MEAN	98.5	81.3	56.8	43.1	22.6	21.1	13.8	4.9	2.2
SD	28.4	28.37244	18.86119	11.79985	6.641432	5.272535	5.150047	1.929515	0.383052
SKEWNESS	0.6	0.37363	0.412263	0.39767	1.376703	1.087455	0.584744	-1.72168	0.113781
KURTOSIS	-0.7	0.37363	-0.47487	-1.08464	2.588861	1.060509	-0.81099	3.400935	-0.95961

Source: Authors Data Analysis, 2016

The frequency factor (K_T) for the return period of the various rainstorms indicates a decrease of value as the storm duration increases this naturally means that the data used is homogenous (as earlier confirmed above) and that storms of shorter duration are likely to reoccur more frequently than those of longer duration (Table 2).

Table 2: Frequency Factor for Return Period T.

Time	0.2H	0.4H	0.6H	0.7H	1H
K_T	$70.91x^{0.3432}$	$52.335x^{0.4124}$	$37.343x^{0.3927}$	$37.343x^{0.3927}$	$16.049x^{0.3318}$
Time	2H	3H	6H	12H	24H
K_T	$16.049x^{0.3318}$	$10.588x^{0.39}$	$6.9791x^{0.6146}$	$3.0383x^{0.4951}$	$1.7813x^{0.2577}$

Source: Authors Data Analysis, 2016.

Results from analysis carried out shows that Intense storms are usually of shorter duration and storms of longer duration tend to be less intense, and the probability of having a very intense storm occurring for a long duration is rare and its occurrence in years increases as the storm intensity increases (Table 3)

Table 3: Rainfall Intensities (mm/hr) in Lokoja

Hrs.	1yr	2yrs	5yrs	10yrs	25yrs	50yrs	100yrs
0.2	66.1	79.5	101.6	122.2	156.1	187.8	226.0
0.4	39.4	49.5	67.0	84.2	113.9	143.2	180.0
0.7	25.4	33.3	47.7	62.5	89.6	117.5	154.2
1	23.4	28.7	37.6	46.0	60.2	73.8	90.4
2	13.7	16.8	22.0	26.9	35.2	43.2	52.9
3	8.7	11.0	14.8	18.6	25.2	31.6	39.7
6	5.3	6.6	9.0	11.4	15.5	19.5	24.6
12	3.1	4.0	5.6	7.2	10.1	13.0	16.8
24	1.6	1.9	2.4	3.0	3.8	4.6	5.6

Source: Authors Data Analysis, 2016.

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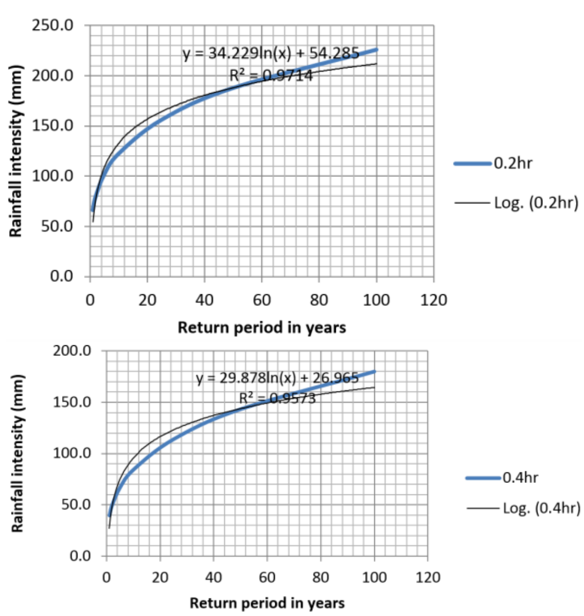


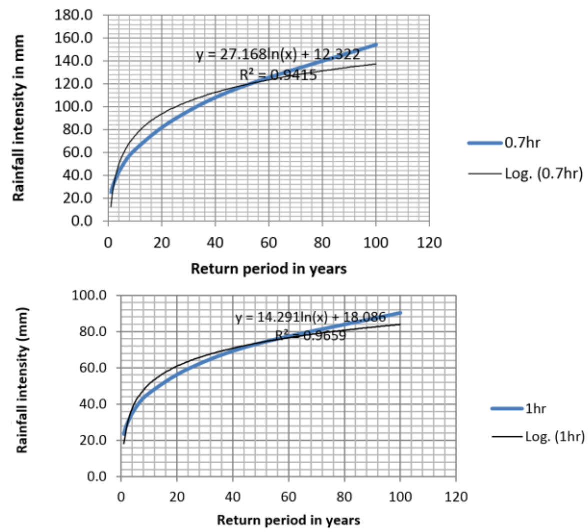
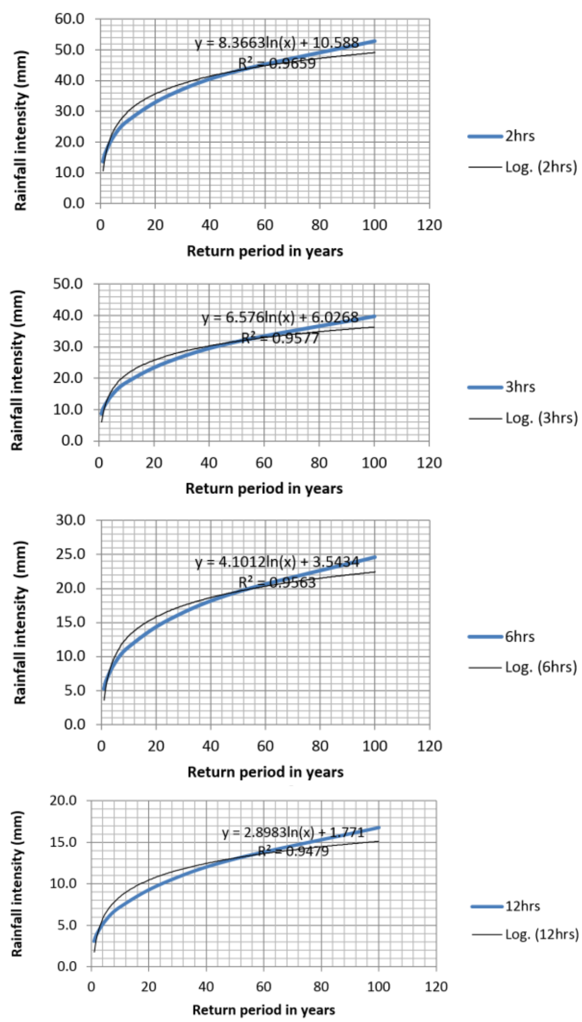


Fig 2: Rainfall Intensity for 0.2hr, 0.4hr, 0.7hr and1hr Return Periods.
Source: Authors Data Analysis, 2016.



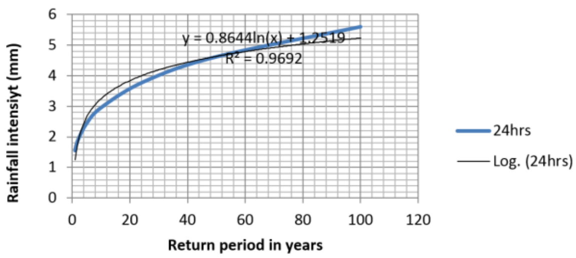


Fig 3: Rainfall Intensity for 2hrs, 3hrs, 12hrs and 24hrs Return Periods

Source: Authors Data Analysis, 2016.

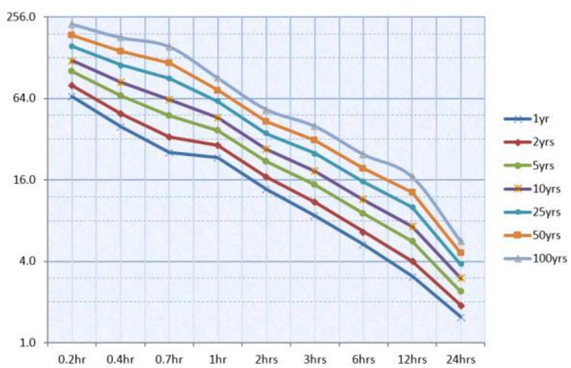


Fig 4: IDF Curve for Lokoja

Source: Authors Data Analysis, 2016

The rainstorms with high intensity in Lokoja were those of relatively short duration (0.2 to 0.7hrs). Their occurrence in any given year could likely trigger a flash flood especially in flood plain areas. However the magnitude of the flood to be triggered by the high rainstorms would vary with different rainfall intensities. As the rainfall intensity increases, the volume of the flood will also increase. The highest rainstorm was that of 0.2hr with rainfall intensity of 226mm (Table 3) which was also the highest value observed. This was a rare storm it's return period being 100 years (Figs 2, 3 and 4). The occurrence of this rainstorm can lead to flash flood and torrential overland flow, rapidly increasing the volume of River Niger and its tributaries. The least value for 0.2hr (duration) had an intensity of 66.1mm with a return period of 1 year; this can also result in water logging and flood when it occurs. The medium rainstorms (1 to 3hrs.) had lower intensities than the high rainstorms (Table 2 and Figs 2 and 3). The magnitudes of flood likely to be triggered by these storms will also be lower than those of the high storms. Also where the water table happens to be high, water from the rainstorm can quickly augment the soil moisture resulting to flood. The highest value of this medium rainstorm intensity was that of 1hr. with an intensity of 90.4mm and a return occurrence of once in 100 years while the lowest value of the one hour rainstorm was 23.4mm with a return period of one year (Table 3). The low rainstorm occurrences in Lokoja (6 to 24 hrs.) had the lowest rainstorm intensity. The highest intensity of this low rainstorm occurrences was that of 6 hours having an intensity of 24.6mm with a return period of 100 years and the lowest intensity was 5.3mm with a return period of one year. The intensities of these rainstorms might not be able to contribute significantly to flood occurrence in Lokoja like those of the medium and high rainstorms.

Intensity, Duration and Frequency of Rainstorm

The plotted IDF curve for Lokoja revealed that rainfall intensity reduces with length of time (Fig. 4). This is a major characteristic of convective rainfall that is higher intensity of rainfall in a shorter duration than in a longer duration. This in the words of Martins *et al* (2012) explains why larger hydrological structures such as dams and bridges are designed for higher return periods while small hydrological structures such as culverts and drainage gutters are designed for low return periods. The study also revealed that for any given year in Lokoja as much as 66mm of rainstorm can be recorded within the duration of 0.2hr., for the same duration 75.5mm rainstorm intensity can occur once in 2years, 101mm once in 5years, 122.2mm once in 25 years, 187.8 once in 50years and the highest rainstorm intensity that can occur in Lokoja within a duration of 0.2hrs (12minutes) is 226.0mm which is expected to occur only once in 100years (Table 3). The implication of this high intensity of rainfall in a short period of time in Lokoja is the likely occurrence of flash flood.

Conclusion

The importance of in-depth knowledge about the characteristics of rainfall in Lokoja cannot be over emphasised as it is useful for environmental planning, engineering construction and agricultural practices. flash flooding tends to be major issue in the urban areas, in such an area, the intensity-duration-frequency will be a good model for flood forecast as it will provide data and accurate knowledge about rainfall characteristics like intensity, duration and how frequent a particular storm of a known duration is likely to re-occur. This will help in determining the type and size of hydrological structures to be constructed.

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