COMPARATIVE STUDY OF THE CHARACTERIZATION OF THE INTENSITY-DURATION-FREQUENCY (IDF) OF THE RAIN OF THE SAVE AND PARAKOU SYNOPTIC STATIONS IN THE REPUBLIC OF BENIN (WEST AFRICA)

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ABSTRACT

The dimensioning of sanitation networks is today one of the major concerns of the scientific community, especially in the preservation of socio-economic, human and environmental challenges in the face of the high rainfall intensities of rare frequency. The purpose of this paper is to characterize rare-frequency rainfall in order to mitigate the damage caused by the high rainfall intensity on the socio-economic, human and environmental issues that they cause in the municipalities of Savè and Parakou.

The methodological approach adopted for this study is based on the collection and processing of rainfall data related to rainfall intensities from the ASECNA pluviogram base over the period 1962 to 1999. The study was carried out by Log-normal law associated with the maximum likelihood method.

The main results of this study result in three different forms of graphic and mathematical modeling of IDF curves. The evolution of these curves shows that the rain intensities and the rain heights have a differential behavior. Similarly, the heavy rain intensities which cause major damage have a duration of less than one hour with t = 5 min corresponding to 312 mm / h at Savéet 379.2 mm / h in Parakou. These results are intended for the design of the hydraulic and sanitation works of the municipalities of Savè and Parakou.

Keywords: Rain of rare frequency, Stakes; Intensity-Duration-Frequency; sizing

1. Introduction

The West African and Central sub-regions are subject to severe and persistent intensity and duration of climate dysfunction since the early 1970s (2I, 2013). The extreme repercussions induced by this phenomenon, in particular the droughts and the recurrent floods of recent years in Benin, have been the subject of several research studies carried out by many researchers in Benin (Bokonon-Ganta, 1987; Boko , 1988, Afouda, 1990, Houndénou, 1999, etc.). These studies show, for the most part, a reduction in the annual rainfall, late start and early end of the rainy season, and a reduction in the number of rain events that suggest a more profound change in the climate system (Yabi et al ., 2010). Extreme rainfall events such as high intensity rainfall often observed are concentrated over short periods of time, generating flooding, sometimes disastrous and even dramatic in socio-economic and agronomic terms (IPCC, 2007). Today, In the urban centers of Benin and in particular in the municipalities of Savè and Parakou, the increasingly widespread disruption of the hydraulic rainwater management works due to exceeding the required hydrological standards. One of the environmental problems perceptible in Savè (Aminou, 2001) is the significant erosion of urban soils, flooding and road degradation, rapid filling of sanitation facilities and water supply.

Although the concern is expressed through declarations of intent and multiple emergency projects, the problem is not addressed in an integrated manner either in a forward-looking document, A thorough research work (Abdoulaye, 2006). In this regard, the study of the Intensity-Duration-Rainfall curves is approached to contribute to the design of hydraulic structures adapted to the climate variability of recent years for a sustainable and rational mobilization and management of urban rainwater and land In the communes of Sava and Parakou.

2. Geographical scope, data and methods

The geographical setting of this study is based on the geographic location of the communes of Savè and Parakou, given the location of the synoptic stations of Savè and Parakou in these communes (Figure 1).

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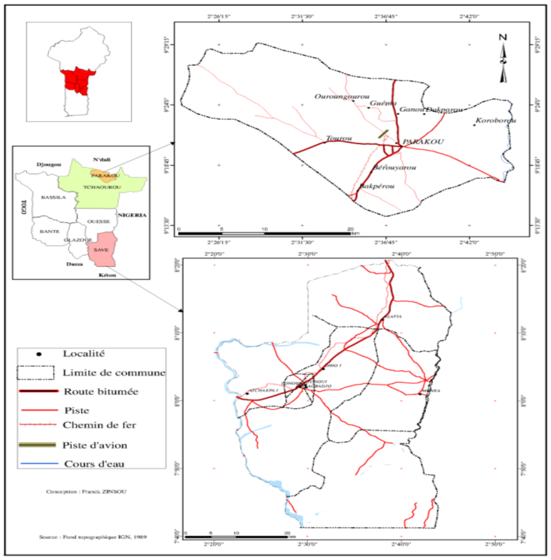

Figure 1: Geographical situation of the communes ofSavè and Parakou

Source: IGN 1999 topographical survey

The commune of Savè is located between 7 ° 40 'and 8 ° 20' north latitude and between 2 ° 20 'and 2 ° 50' east longitude. It is bounded on the north by the commune of Ouessè, on the south by the commune of Kétou, on the east by the Republic of Nigeria and on the west by the Communes of Dassa and Glazoué. The commune of Parakou is located between 9 ° 13 'and 9 ° 29' north latitude and between 2 ° 26 'and 2 ° 42' east longitude. It is bounded to the north by the N'Dali commune, to the east, to the west and to the south by the commune of Tchaourou. It covers an area of about 441Km with an average altitude of 350m.

The data used are rainfall data for time intervals of less than one day related to the pluviograms of the synoptic stations of Savè and Parakou. These data have been extracted from the file of the Agency for Safety and Air Navigation (ASECNA). The period under consideration stretches from 1962 to 1998 in Savè and from 1962 to 1999 in Parakou.

Methods of Data Processing

After having followed the computer processing in Excel, the maximum intensities of the rains are calculated according to the durations t by the following formula:...

$$I_{max} = \frac{\Delta h}{\Delta t}$$

With Imax = Maximum intensity in mm / h;

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Δh = rainfall in mm per time interval considered;
Δt = duration of the downpour considered.

After calculating and removing the maximum annual intensities of each study station, Excel, Hydraccess and Safarhy were used for the statistical adjustment of the data and the presentation of the results in graphs. The Log-normal law associated with the method Of the maximum likelihood corresponds to an appropriate estimate of the high rainfall intensities as a function of the corresponding return periods.
With the calculation methods of the Montana, Talbot and American coefficients, a graphical and mathematical modeling of these maximum annual rainfall intensities is carried out. These methods are most commonly used for estimating rainfall intensities at hydrological stations. In this study, they allowed to model the IDF relationship in the following mathematical forms:

- Imax = a t-b for Montana;

- Imax = a.Tn .t-b for the American formulation;

- Imax = a / (b + t) for Talbot;

Or

Imax is the maximum intensity in mm / h

T is the duration of the shower in minutes

T is the return period

A, b, n are constant coefficients or local parameters depending on a given study station.

The methods for calculating the Montana, American and Talbot coefficients, as used in this study, allow to model the intensity of the rains according to its duration and its recurrence period.

Using the least squares method, the results obtained are compared with those obtained by CIEH in 1984. The correlation coefficients obtained from this comparison justified the effectiveness of the methodological approach adopted.

3. Results

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3.1. Graphical modeling of the rain IDF of Savè and Parakou

3.1.1 Montana Method

Figure 2 shows the graphical representation of the rainfall intensities as a function of the period of return to Savè and Parakou.

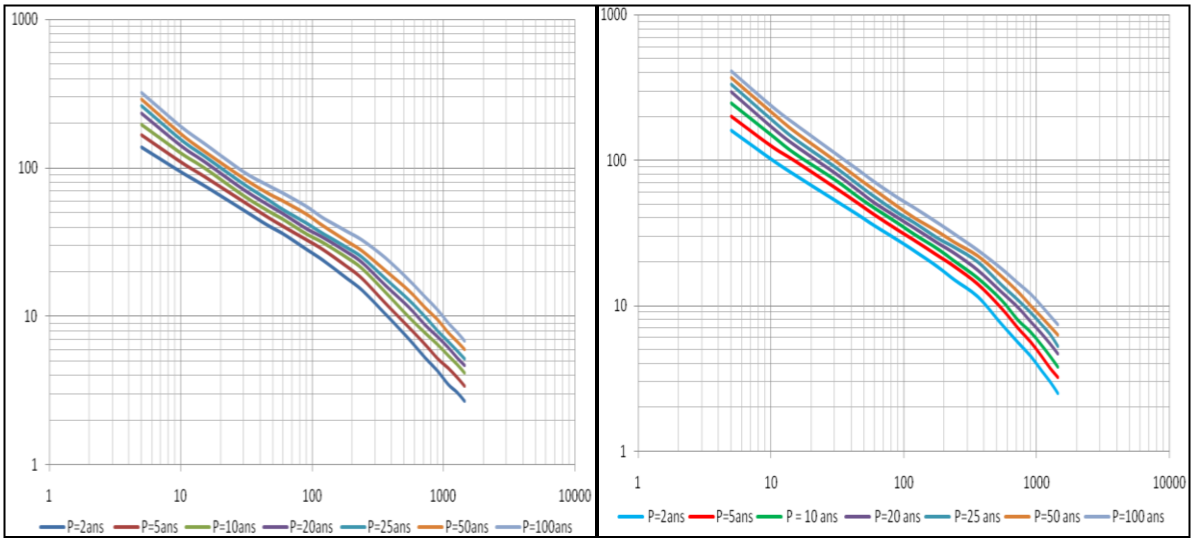

Figure 2: Evolution of maximum rainfall intensities per period of return to Savè and Parakou (Montana method)
Source: l'ASECNA Data Processing, 2014

From the analysis of FIG. 2, it is found that the IDF relationship describes at Savè as at Parakou a family of parallel curves represented in a system of doubly logarithmic axes. From the evolution of such a relation, the intensities are all the smaller because the duration t increases and becomes more and more strong with the periods of return.

Similarly, these IDF curves have a contrary arrangement to those of the rainfall heights often represented in a double logarithmic axis system. This makes it possible to deduce that the rainfall intensities and the rainfall heights do not behave in the same way. Where decision-making on rainfall heights may not always be consistent with those to be taken into account for rainfall intensities.

In a logic of well characterizing this evolution of the IDF curves, there is also a graphical representation of this relationship of the IDFs by the Talbot method.

3.1.2 Talbot Method

Figure 3 shows the graphical representation of rainfall intensities as a function of the period of return to Savè and Parakou....

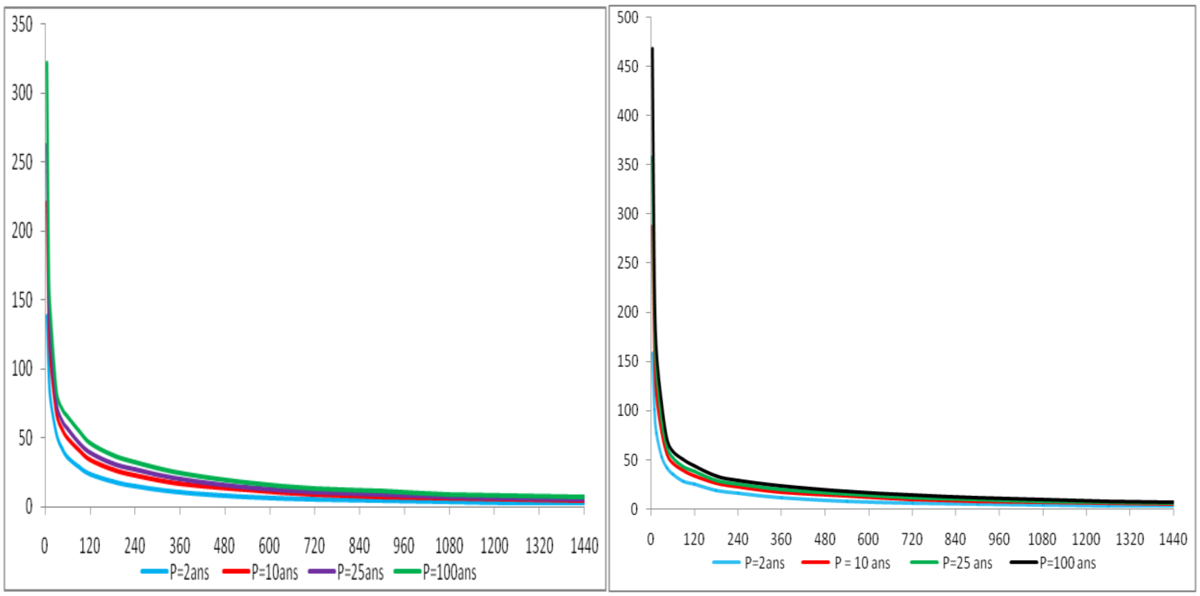

Figure 3: Evolution of maximum intensities per period of return to Savè and Parakou (Talbot method)
Source: l'ASECNA, Data Processing, 2014

From the analysis of FIG. 3, there is a convergence and a decrease in the evolution of the rain intensities towards a duration t of value equal to 24 hours. This decline remains uniform for all return periods and the strongest intensities correspond to high return periods. This confirms the convergent and decreasing evolution observed in the Montana method. Moreover, it is found that the high rainfall intensities which cause major damage to Savè and Parakou have a duration of less than one hour with t = 5 min corresponding to 312 mm / h at Savè and more than 379, 2 mm / h at Parakou. Consequently, the evolution of rain intensities is not only a function of the return periods but also of the duration t.
As a result of the graphical modeling of the IDFs, a mathematical model was used to propose mathematical formulas for a good estimation of these rainfall intensities.

3.2 Mathematical modeling of the Savè and Parakou rainfed IDF

The mathematical modeling of the rainfall intensities of Savé and Parakou is obtained by calculating the coefficients of Montana, Talbot and the American method.

3.2.1 Montana Method

Table I: presents the result of the calculation of the coefficients a and b of the method of Montana to Savè and to Parakou.

Table I: Presentation of equations of the rainfall IDF curves of Savè and Parakou (Montana method)

TIME		EQUATIONS OF MONTANA (I in mm / h and t in minutes)			
		SAVE		PARAKOU	
Return Period	**Interval**	$I = a\,t^{-b}$	R^2	$I = a\,t^{-b}$	R^2
P = 2 ans	$5' \le t \le 1h$	$I = 308t^{-0,5}$	0,99	$I = 420t^{-0,6}$	0,99
	$2h' \le t \le 24h$	$I = 950t^{-0,8}$	0,99	$I = 2150t^{-0,9}$	0,98
P = 5 ans	$5' \le t \le 1h$	$I = 400t^{-0,5}$	0,99	$I = 620t^{-0,6}$	0,99
	$2h' \le t \le 24h$	$I = 1300t^{-0,8}$	0,99	$I = 3000t^{-0,9}$	0,98
P = 10 ans	$5' \le t \le 1h$	$I = 480t^{-0,5}$	0,99	$I = 770t^{-0,6}$	0,99
	$2h' \le t \le 24h$	$I = 1550t^{-0,8}$	0,98	$I = 3530t^{-0,9}$	0,99
P = 20 ans	$5' \le t \le 1h$	$I = 555t^{-0,5}$	0,99	$I = 900t^{-0,6}$	0,98
	$2h' \le t \le 24h$	$I = 1800t^{-0,8}$	0,98	$I = 4000t^{-0,9}$	0,99
P = 25 ans	$5' \le t \le 1h$	$I = 560t^{-0,5}$	0,99	$I = 900t^{-0,6}$	0,99
	$2h' \le t \le 24h$	$I = 1850t^{-0,8}$	0,98	$I = 4000t^{-0,9}$	0,98
P = 50 ans	$5' \le t \le 1h$	$I = 600t^{-0,5}$	0,99	$I = 1150t^{-0,6}$	0,99
	$2h' \le t \le 24h$	$I = 2200t^{-0,8}$	0,98	$I = 4300t^{-0,9}$	0,99
P = 100 ans	$5' \le t \le 1h$	$I = 570t^{-0,5}$	0,98	$I = 1200t^{-06}$	0,98
	$2h' \le t \le 24h$	$I = 2400t^{-0,8}$	0,98	$I = 4700t^{-0,9}$	0,98

Source: l'ASECNA, Data Processing, 2014

From the analysis of Table I, it appears that for the time interval $5 ' \le t \le 1$ h, the coefficients b = 0.5 to Save and b = 0.6 to Parakou are stable whatever the return period. This is the same for the interval $2h \le t \le 24h$ with the coefficients b = 0.8 to Save and b = 0.9 to Parakou. These calculated values offer a correlation coefficient R2 which varies between 98 and 99. The equation of the rainfall IDF curves determined for Savè and Parakou is in the form I = a t - b. The coefficients thus determined are to be included in the flow calculation formulas by the design engineers of the hydraulic structures for better management of the risks of runoff, erosion

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or flooding. The main point concerning the highest rainfall intensities in this study environment is in the time interval 5 '$\leq$ t $\leq$ 1 h.

3.2.2 American method

The second method tested for the mathematical modeling of rain intensities in this study is the American method.

Table II shows the result obtained.

Table II: Presentation of the equations of the American method

Station	Coefficients and Equations of the American formulation (I in mm / h)			
	$I = a.T^n. t^{-b}$			
	A	**n**	***The return period T in year and the duration t in minute*** / *Equations*	**b**
Savè	250	0,2	$I = 250.T^{0,2}.t^{-0,5}$	*0,5*
Parakou	350	0,3	$I = 350.T^{0,3}.t^{-0,6}$	*0,6*

Source: l'ASECNA, Data Processing, 2014

From Table II, it is found that the return period T and the duration t are the only ones which vary. The coefficients a, n and b are constant and vary only with respect to each study station. This rainfed IDF model is in the form: I = a.Tn. Does b. Such a form offers an ease of estimating the rain intensities over the entire range from 5 minutes to 24 hours by fixing beforehand the period of recurrence T and the duration t according to the study to be carried out. This equation offers an ease of estimating the intensities I corresponding to each return period or the duration t.

3.2.3 Talbot Method

Table III: Presentation of the calculated coefficients a and b and the curve equations Intensity-Duration-Frequencies of Savè and Parakou rains (Talbot method)

TIME	TALBOT EQUATIONS (I in mm / h and t in minutes)	
	SAVE	**PARAKOU**

Return Period	I = a / (b+t)	R^2	I = a (b+t)	R^2
2 ans	I = 1520 / (6+t)	0,98	I = 1850 / (6+t)	0,99
5 ans	I = 2150 / (6+t)	0,98	I = 2580 / (6+t)	0,98
10 ans	I = 2450 / (6+t)	0,98	I = 3170 / (6+t)	0,98
20 ans	I = 2800 / (6+t)	0,97	I = 3500 / (6+t)	0,97
25 ans	I = 2950 / (6+t)	0,97	I = 3750 / (6+t)	0,97
50 ans	I = 3200 / (6+t)	0,97	I = 4000 / (6+t)	0,97
100 ans	I = 3500 / (6+t)	0,96	I = 5000 / (6+t)	0,96

Source: l'ASECNA, Data Processing, 2014

From the analysis of Table III, it appears that the coefficients a and b of the Talbot method are calculated with a correlation of R2 which varies between 0.96 and 0.99. This method has for mathematical formole: I = a / (b + t). It makes it possible to estimate the intensity I corresponding to each return period as a function of the duration t.
Of all the different methods of mathematical modeling experimented: be, I = a t - b, I = a.Tn. T-b and I = a / (b + t), there is no significant difference. However, it is important to report that the Montana method, which presents intensity I in the form of: I = a t, gives more reliability in the estimation of data than the others.

3.3. Comparison of the results obtained with those existing for the CIEH since 1984

The comparison made it possible to see the evolution of the results obtained in relation to those of CIEH proposed in 1984 in order to appreciate the metrological approach adopted.

Table IV: Correlation between proposed data and that of the CIEH (T = 10 years) in Savè and Parakou

Stations	Interval Considered	No time	CIEH data (mm / min)	Proposed Data (mm / min)	R^2	$\sum mc = 1-R^2$	correlations
Savè	**5' ≤ t ≤ 24h**	**5**	**183,6**	**221**	**0,98**	**0,02**	**y = 0,732x + 1,103**

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		10	**160,2**	**128,4**			
		15	**141,2**	**103**			
		30	**105,4**	**67,2**			
		45	**84,1**	**56**			
		60	**68,5**	**50**			
		90	**49,7**	**41**			
		120	**40,6**	**34,4**			
		240	**25,6**	**23**			
		720	**10,2**	**9**			
		1440	**5,1**	**4,5**			
Parakou	**5' ≤ t ≤ 24h**	**5**	**199,2**	**288**	**0,98**	**0,02**	**y = 0,977x – 4,658**
		10	**159,0**	**160,4**			
		15	**125,6**	**116**			
		30	**85,2**	**78**			
		45	**71,7**	**56,3**			
		60	**62,3**	**47**			
		90	**48,7**	**39**			
		120	**38,4**	**34**			
		240	**24,7**	**22,3**			
		720	**8,9**	**10**			
		1440	**4,5**	**5**			

When the data proposed by CIEH and those calculated and estimated in this study are observed, a slight difference is observed for the intensities of 5 min in Parakou and Savè. This difference may be due to influences of climatic variability or to a strong gale of wind during the rainfall record. Apart from these 5-minute steps, all the other steps from 10min to 24h are substantially in line with those of CIEH. The sum of the least squares (Σ mc = 0.02) is very small and justifies that there are no significant differences between the proposed data and that of CIEH. The coefficients of determination resulting from this comparison in Savè and Parakou give R2 = 0.98. This value of R2 = 0.98 makes it possible to say that the adjustment methods and the law used for this study are effective.

Conclusion

The present research found that extreme rains, which often cause large-scale socio-economic and environmental damage, are concentrated in short-term rains with high intensities, the highest being 312 mm / h at Savè and 379.2 In Parakou. They are rainfalls whose frequency of occurrence is between 2 years and 100 years for the entire period 1962 to 1999. Consequently, the results obtained must be taken into account for the design of the hydraulic and sanitation structures both for the Urban and rural development. This is to spare the populations of possible disasters and to ensure their sustainable development in the face of extreme climatic extremes.

The application of the Intensity-Duration-Rainfall curves to the evaluation of erosion and flooding risks in the Okpara watershed in Benin will be discussed.

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