DETERMINING IDF EQUATIONS FOR THE STATE OF RONDÔNIA

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ABSTRACT: This study aimed to estimate the Intensity-Duration-Frequency (IDF) function of extreme pluviometric events for the State of Rondônia in Brazil. This study used forty-one pluviometric stations with over 10 years of historic data. Data were analyzed following the Gumbel distribution and related (through disaggregating of daily rains) to return periods comprising from 2 to 100 years and pluviometric durations from 5 minutes to 24 hours. Furthermore, areas of influence for the applicability of IDF equations were determined by Voronoi diagrams. The IDF equations were validated with the help of the regression coefficient (r^2) and the Wilcoxon-Mann-Whitney hypothesis test showed that its use is feasible.

KEYWORDS: Heavy rainfalls; IDF Curve; Socio-environmental impacts; Hydrostatistics.

DETERMINAÇÃO DE EQUAÇÕES IDF PARA O ESTADO DE RONDÔNIA

RESUMO: Este estudo objetivou estimar a função Intensidade-Duração-Frequência (IDF) de eventos pluviométricos extremos para o estado de Rondônia. Utilizou-se 41 estações pluviométricas, com séries históricas acima de 10 anos. Os dados foram analisados pela distribuição de Gumbel, e relacionados, por meio da desagregação de chuva diária, para períodos de retorno compreendendo 2 a 100 anos e durações pluviométricas de 5 minutos a 24 horas. Além disso, confeccionaram-se áreas de influências para a aplicabilidade das equações IDF, por meio de diagramas de Voronoi. As equações IDF foram validadas com o auxílio do coeficiente de regressão (r^2) e o teste de hipótese de Wilcoxon-Mann-Whitney evidenciou ser viável o seu uso.

PALAVRAS-CHAVE: Chuvas intensas; Curva IDF; Impactos socioambientais; Hidroestatística.

1. INTRODUCTION

Rainfall is one of the most important meteorological variables for climate studies of any region. Such importance is due to the consequences that the lack or excess of rainfall may cause (Davis and Naguetti 2001). Because of its wide influence in populated areas, positive or not, rain can be considered the main source of water supply for human and economic activities (Almeida et al., 2011).

Knowledge of extreme hydrological events is a requirement for designing drainage projects, waterproofing and other engineering works, whether in urban or rural areas, since it allows the designer to consider the risks involved with carrying out the work and assign the best alternative from an economic point of view, without disentangling oneself from the technical issues of performance and security.

In this sense, a widely used form for the characterization of extreme rainfall in a given location is the use of intensity-duration-frequency curves (IDF). These curves represent a very important tool in the design and construction of different hydrological structures in water management (Rodriguez et al., 2014).

The IDF curves are semi-empirical mathematical models that predict the precipitated intensity by the use of information such as duration and temporal distribution. It is noteworthy that the inference of extreme rainfall is possible due to such events fit the probability distributions, providing they are statistically modeled.

In Brazil, the precipitated volumes are essentially quantified by rainfall stations in so-called records of daily rainfall and are the most accessible, not only by the series size, but also by the density of networks (Hernandez, 2008). However, this data collection methodology causes an obstacle in the generation of IDF curves due to the unavailability of rainfall data with shorter durations, which are essential in the modeling process of these curves.

Because of this problem, the rain disaggregation method of 24 hours, by the Environmental Sanitation Technology Company of the State of São Paulo - CETESB (1979 cited Tucci 2009) is presented as a solution since it generates synthetic series with length into smaller intervals by means of coefficients that transform a rain of 24 hours in others of shorter duration.

It is noteworthy that in the country territory, except for the more developed regions, there are regions that lack the development of these models for its territorial extensions, such as the state of Rondônia, a state which practically has quite limited information on heavy rainfall due the the small amount of available hydrological data.

Located in the Western Amazon, the state of Rondônia has shown some rainfall events that caused disasters in the region in recent years, as described in the Brazilian Atlas of Natural Disasters (1991-2012). From 1991 to 2012, 19 cases of floods were officially registered and characterized as disasters, in which

ISSN: 1980-055x (Impressa) 2237-8642 (Eletrônica)

the worst ones happened between 1997 and 2010 and also there were 10 official records of floods in the same period. Similarly, in 2014 Rondônia declared state of emergency due to floods between January and April, when several Amazon southwestern rivers presented exceptional levels. The Madeira River in Porto Velho (Rondônia), reached a record of 19.74 meters, more than three meters above the emergency quota established by the local public agencies, which is 16,68 meters (Franca 2015).

Thus, it is of utmost importance to know and predict the characteristics of rainfall in the region, highlighting the elucidation of its maximum intensity, duration and the period that such an event may recur.

In view of the exposed above and taking into account the importance of generating new jobs related to rainfalls in the state of Rondônia for future reference, this study aimed to broadly estimate the IDF functions from rainfall data from rainfall stations available on the website of the National Water Agency.

2. MATERIALS AND METHODS

2.1 FIELD OF STUDY

The State of Rondônia (Figure 1) is located in the Western portion of the Amazon between the parallels 7º 58' and 13º 43' and South meridians 59º 50' and 66º 48' Longitude West. Rondônia is comprised of 52 cities, being the State capital, Porto Velho, the most populous city with 428.527 inhabitants (IBGE, 2010).

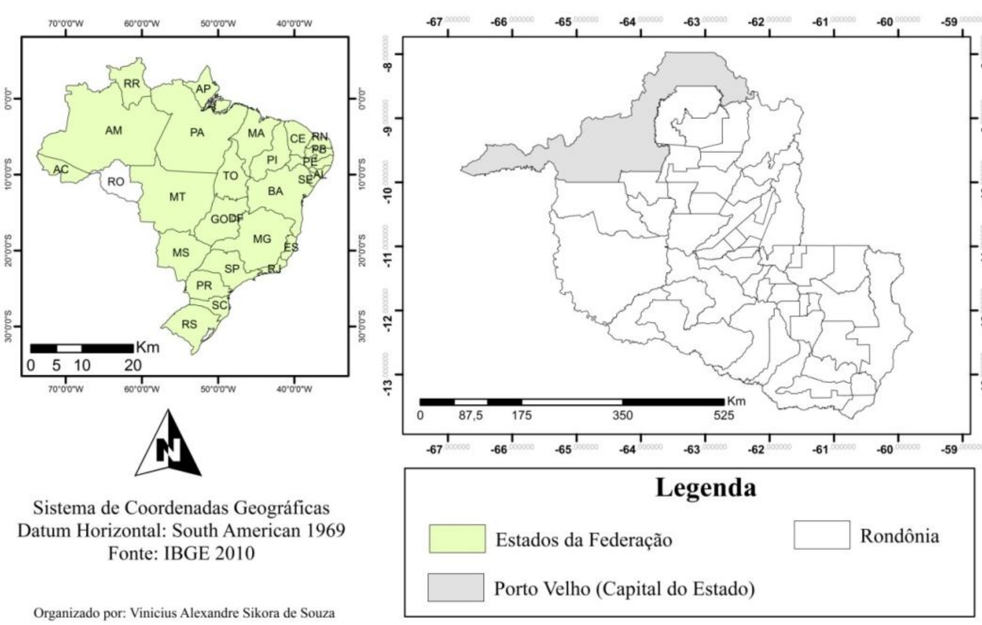

Figure 1 – Location of the State of Rondônia

The state of Rondônia has altitudes ranging between 70 and 600 meters, and its main relief units: Amazon Plains; Depressions (Southern Amazon, Guaporé and Solimões); Highlands (Meridional Amazon and Parecis); Wetland of Guaporé. The types of vegetation found in the region are the Open Ombrophylous Forests, Dense Ombrophylous Forests (Amazon Forest), Seasonal Semidecidual Forests, Savannah and Alluvial Vegetation, with predominantly Dense forests northwest of the State (Brazil, 1978).

2.1.2 Climate

In the Köppen classification, the climate of the State of Rondônia is characterized as AW (tropical hot and humid) and a well defined dry season during the winter season, when a moderate drought occurs with a lower rainfall deficit at 50 mm/month. (Rondônia, 2009).

The rain in Rondônia is monsoon-like and therefore only occurs during the time of year when the continent is heated above the temperature levels of the ocean surface and becomes a convection center where there is ample moisture supply for condensation (Butt et al. 2011).

The annual rainfall in the central region of the state is on average above 2,000 mm, with relative humidity of the air in the average of 82% and average annual temperatures ranging from 24°C during the rainy season to 25°C in the dry season (Aguiar et al., 2006; Webler et al. 2007).

This region, according to the Secretary of State Environmental Development - SEDAM - (2009), does not suffer major continental influence, for example, greater or lesser distance from the sea.

2.2. DATA ANALYSIS

2.2.1 Data Acquisition

Precipitation data used in this study was obtained from the database provided by the National Water Agency (ANA). It is noteworthy that the information in this database have been used in several similar studies, among them: Arantes et al. (2009); Butt, Oliveira and Costa (2011); Fietz and Comunell (2006); and Oliveira et al. (2010).

This agency keeps in its records data of rainfall accumulated in periods from one day to 93 rainfall stations in the state of Rondônia, however, only 41 presented a set of data with a time series of more than 10 years, with such

ISSN: 1980-055x (Impressa) 2237-8642 (Eletrônica)

information featured in the study of CETESB (1979, cited Fietz e Comunell, 2006) as a requirement for making the IDF equations, which are the subject of this study. Thus, only the data from these 41 stations were used.

Table 1 contains some more detailed information of the stations used in the study and in Figure 2 we display their location.

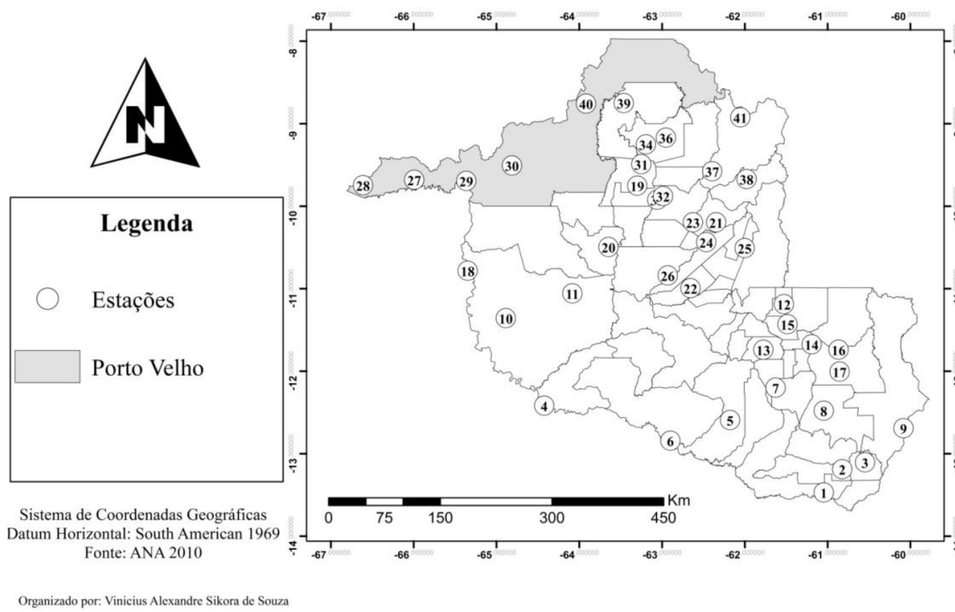

Figure 2 – Location of rainfall stations in the state of Rondônia used in this study.

Table 1 – Data from sampled rainfall stations

Code	Series (years)	Effective months	City
1360002	1983 – 2010	333	Pimenteiras do Oeste
1360001	1983 – 2010	336	Cerejeiras
1360000	1983 – 2010	334	Colorado do Oeste
1264000	1983 – 2010	329	Costa Marques
1262001	1999 – 2010	139	Alta Floresta do Oeste
1262000	1980 – 2010	352	Costa Marques
1260001	1967 – 2003	337	Vilhena
1261001	1999 – 2010	130	Parecis
1261000	1983 – 2006	260	Chunpinguia
1260001	1967 – 2003	337	Vilhena
1164001	1983 – 2002	229	Guajará-Mirim
1164000	1976 – 1989	167	Guajará-Mirim
1161003	1999 – 2010	131	Ministro Andreazza
1161002	1983 – 2010	315	Rolim de Moura
1161001	1980 – 2010	372	Pimenta Bueno
1161000	1977 – 2010	395	Cacoal

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1160002	1982 – 2010	334	Pimenta Bueno
1160000	1977 – 2010	393	Pimenta Bueno
1065002	1972 – 2010	451	Guajará-Mirim
1062004	1986 – 2010	285	Theobroma
1062003	1983 – 2010	324	Mirante da Serra
1062002	1978 – 2010	383	Jaru
1062001	1977 – 2010	399	Jaru
1061003	1987 – 2010	285	Ouro Preto do Oeste
1061001	1975 – 1997	262	Ji-Paraná
966001	1982 – 2010	316	Porto Velho
966000	1977 – 2010	404	Porto Velho
965001	1976 – 2010	377	Porto Velho
964001	1978 – 2002	290	Porto Velho
963009	1997 – 2010	162	Ariquemes
963006	1983 – 2001	223	Ariquemes
963004	1980 – 2010	366	Ariquemes
963001	1977 – 2010	387	Porto Velho
963000	1975 – 2010	420	Ariquemes
962001	1981 – 2007	308	Porto Velho
962000	1978 – 2010	378	Machadinho do Oeste
961003	1987 – 2009	273	Machadinho do Oeste
863003	1975 – 2002	297	Candeias do Jamari
863000	1961 – 2007	564	Porto Velho
862000	1977 – 2010	385	Machadinho do Oeste

2.2.3 Construction of IDF Equations

Firstly, in order to estimate the IDF equations, we obtained the maximum rain height of "one day" of each year for the historical series of each rainfall station analyzed, thus constituting the series of annual maximum rainfall.

Secondly, the data was organized in a descending order, with the arithmetic mean and the standard deviation of the computed samples. This procedure allowed us to statistically analyze the probability and return period of heavy rain through the Gumbel distribution method.

The reduced variable of Gumbel (y) was obtained by Equation 1, as recommended by Gumbel (2004).

$$y = \frac{s_y}{s_x}\left[x_i - \left(x_m - s_x \frac{y_m}{s_y}\right)\right] \qquad (1)$$

where:

s_x – Standard deviation of the series;

x_i – Value of one element of the sample;

x_m – Mean of the sample of finite annual series of n values;

s_y – Standard deviation, fixed value;

y_m – Average reduced variable (y), tabulated as a function of sample number data.

The return period (Tr), defined as the average time in years in which any one of rain value is equaled or exceeded at least once is estimated by Equation 2. This function expression is in the base of the neperianos logarithms (e)

$$Tr = \frac{1}{1-e^{-e^{-y}}} \quad (2)$$

After this procedure, the data were then plotted on a graph to present the same characteristics of log-probability paper, also known as Gumbel paper, that is, the points corresponding to the heights of rain (p) were on the ordinate in arithmetic scale, and the return period, in years, corresponding in the abscissa, on a logarithmic-probability scale.

After this, a line was set for the data in that chart, which realized the extent of the data analyzed since they showed the same adjustment coefficient (r^2) ranging from 89% to about 100%, as shown in Table 2.

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Table 2 – Adjustment coefficient of estimated equations for the data from the analyzed stations

Code	Station	r²	Code	Station	r²
1360002	1	0,901	1062003	22	0,896
1360001	2	0,967	1062002	23	0,941
1360000	3	0,962	1062001	24	0,964
1264000	4	0,970	1061003	25	0,918
1262001	5	0,968	1061001	26	0,954
1262000	6	0,922	966001	27	0,931
1261001	7	0,984	966000	28	0,943
1261000	8	0,987	965001	29	0,988
1260001	9	0,978	964001	30	0,961
1164001	10	0,929	963009	31	0,896
1164000	11	0,950	963006	32	0,894
1161003	12	0,926	963004	33	0,967
1161002	13	0,950	963001	34	0,960
1161001	14	0,982	963000	35	0,971
1161000	15	0,938	962001	36	0,962
1160002	16	0,976	962000	37	0,970
1160000	17	0,951	961003	38	0,954
1065002	18	0,982	863003	39	0,963
1063001	19	0,974	863000	40	0,995
1063000	20	0,991	862000	41	0,919
1062004	21	0,980	-	-	-

Thus, it was possible to estimate the maximum rainfall lasting "one day" for various return periods and even extrapolate the information for larger return periods than those contained in the range of such data.

After obtaining the heights of rainfall for the periods from 2 to 100 years, we estimated the probable maximum average intensities for all rain durations from 5 minutes to 24 hours through the disaggregation of daily rainfall using the ratios of average relations at national level (Table 3) obtained by Cetesb (1979), explained in Tucci (2009).

Table 3 – Ratios at national level of relations between durations

Relation	Ratio
5min/30min	0,34
10min/30min	0,54
15min/30min	0,70
20min/30min	0,81
25min/30min	0,91
30min/1h	0,74
1h/24h	0,42
6h/24h	0,72
8h/24h	0,78
10h/24h	0,82
12/24h	0,85
24h/1dia	1,14

Source: Tucci (2009)

To get the information of maximum heights for the periods and durations intended, the IDF equation was generated for the areas of influence of each rainfall station in Rondônia through the establishment of the constants - K, a, b and c – by the method of least squares. For the general IDF equation, Equation 3, which according to Villela and Mattos (1975) is the most widely used mathematical model to express the IDF regarding precipitation. The LAB Fit® software (Silva et al., 2004), indicated by its creators as an effective tool for curve fitting.

$$i_m = \frac{K.Tr^a}{(t+b)^c} \quad (3)$$

where:
i_m – Maximum average rainfall intensity, mm/h;
t – Duration (min);
Tr – Return period (year);
K, a, b, c – Parameters related to locality.

2.2.4 Analysis of Efficiency of IDF Curves

When verifying the efficiency of the IDF equation proposed by this study, we used the regression coefficient (r²) of function adjustment to the points and conducted the Wilcoxon-Mann-Whitney hypothesis test, available from MINITAB® Statistical Software, 16.0 demo (Minitab 2011), to verify if the measured and modeled data, according to the Gumbel distribution, differ statistically from the data estimated by the IDF function, being established as a null hypothesis (H0) that such data are the same, in other words, that the average of the differences between the modeled data and estimated data is equal to the magnitude 0 and, as an alternative hypothesis (H1), that they differ among themselves, meaning that the average of this difference is not equal to 0.

The decision criterion was based on the interval built for these differences, with a confidence level of 99.5%. If a 0 value is contained in the range, the null hypothesis is accepted because the average is statistically equal to 0, otherwise the alternative hypothesis would be accepted, since the previous statement becomes untrue

We point out that Prazeres Filho et al. (2010) report that the Wilcoxon-Mann-Whitney test is a nonparametric test, which leave out the original data distribution and is therefore called distribution-free tests. The same is suitable for testing whether two samples are identical or not, moreover its use occurs when the variables are measured in at least ordinal scale level, being the same an alternative to the paired t-test.

When it comes to the testing of the waste produced by the differences in the magnitude of extreme rainfall disaggregated data and modeled by the Gumbel distribution (x_M) and the estimated data by the IDF equations ellaborated in this study (x_E), we performed an analysis of the average standard error (ASE) Equation 4; normalized mean error (NME), Equation 5; and medium multiplicative error (MME), Equation 6. All these analyses are explained in the work of Moog and Jirka (1998).

$$ASE = \sqrt{\left[\sum_{i=1}^{n} \frac{(x_E - x_M)_i^2}{N}\right]} \quad (4)$$

$$NME = \frac{100\%}{N} \sum_{i=1}^{n} \left(\frac{x_E - x_M}{x_M}\right)_i \quad (5)$$

$$MME = e^{\left[\frac{\sum_{i=1}^{n} \left| ln(x_E / x_M)_i \right|}{n}\right]} \quad (6)$$

2.3 DETERMINATION OF THE AREAS OF INFLUENCE OF IDF CURVES

Assuming that the municipalities in the state of Rondônia have large territorial extensions, this study chose to indicate the use of IDF equations generated not for each municipality, but rather to the area of influence of the equation.

The theory used for the construction of those areas of influence was the Voronoi diagram, in which each area represents a cell on this diagram, which has a characteristic of intersection of all half-spaces defined by bisectors, in other words, perpendicular bisectors of lines connecting two adjacent rainfall posts, which were used in the equation (Boots 1986).

The creation of the areas was performed using the Quantum Gis® software (SHERMAN et al., 2011), when firstly the geographic coordinates of the sampled rainfall stations, present in a table, were converted to a file in the *shape file* format (.shp), this being subsequently used to create the polygons of influence when selecting the program's menu bar the "Voronoi diagram". After this procedure, we intersected the diagram generated with the vector file in the State of Rondônia, thus enabling the generation and identification of areas of influence of rainfall stations in the State.

3 RESULTS AND DISCUSSION

3.1 IDF CURVES

In order to verify the applicability areas of IDF equations, we built Figure 3 for the State of Rondônia, whose constants at each location are contained in Table 4. By examining this figure, it is clear that virtually the entire state was covered with the exception of a small area in the far north, belonging to the city of Porto Velho. Failure to include this region in the areas of influence of IDF curves was due to the spatial arrangement of stations used for this study, which prevented their inclusion in the interpolation phase carried out by the software.

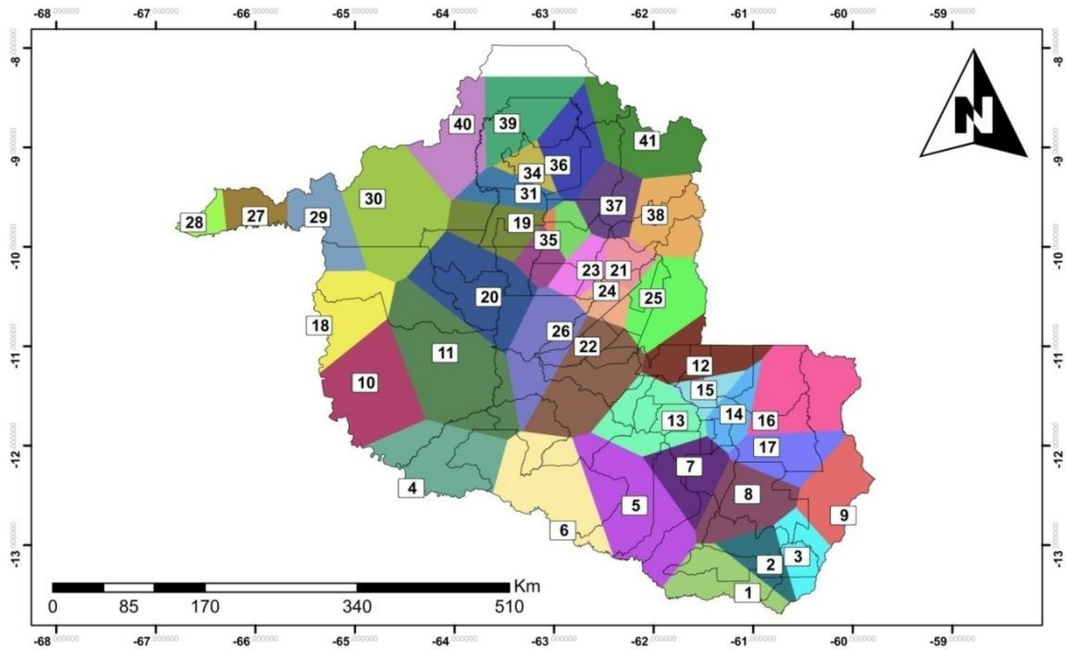

Figure 3 – Areas of influence of the IDF equations for their sampled rainfall stations in the State of Rondônia

For this reason, it is recommended for the northern portion of the city of Porto Velho the adoption of the equation for the area of influence 39, since this is the closest area to the locality with missing data and possibly both regions have similar climate characteristics, producing a minor error when using that equation.

Table 4 – Coefficients of IDF equations for the State of Rondônia

Equation	Code	K	a	B	c
1	1360002	865,211	0,284	13,868	0,714
2	1360001	922,522	0,242	13,868	0,714
3	1360000	926,887	0,213	13,868	0,714
4	1264000	786,164	0,244	13,868	0,714
5	1262001	822,730	0,220	13,868	0,714
6	1262000	829,215	0,206	13,868	0,714
7	1261001	801,558	0,205	13,868	0,714
8	1261000	763,368	0,247	13,868	0,714
9	1260001	734,652	0,233	13,868	0,714
10	1164001	684,101	0,271	13,868	0,714
11	1164000	731,896	0,146	13,868	0,714
12	1161003	778,344	0,172	13,868	0,714
13	1161002	895,658	0,204	13,868	0,714
14	1161001	867,613	0,183	13,868	0,714
15	1161000	941,599	0,231	13,868	0,714
16	1160002	819,248	0,203	13,868	0,714
17	1160000	940,299	0,226	13,868	0,714
18	1065002	935,889	0,239	13,868	0,714
19	1063001	973,900	0,207	13,868	0,714
20	1063000	1038,794	0,293	13,868	0,714
21	1062004	873,381	0,196	13,868	0,714
22	1062003	742,118	0,189	13,868	0,714
23	1062002	926,701	0,173	13,868	0,714
24	1062001	918,014	0,204	13,868	0,714
25	1061003	963,613	0,161	13,868	0,714
26	1061001	951,542	0,198	13,868	0,714
27	966001	699,870	0,208	13,868	0,714
28	966000	918,097	0,190	13,868	0,714
29	965001	930,547	0,314	13,868	0,714
30	964001	703,547	0,322	13,868	0,714
31	963009	875,778	0,244	13,868	0,714
32	963006	933,698	0,255	13,868	0,714
33	963004	945,314	0,188	13,868	0,714
34	963001	981,296	0,182	13,868	0,714
35	963000	1053,185	0,206	13,868	0,714
36	962001	1093,628	0,216	13,868	0,714
37	962000	945,329	0,174	13,868	0,714
38	961003	903,301	0,206	13,868	0,714
39	863003	851,672	0,177	13,868	0,714
40	863000	1774,359	0,332	13,867	0,714
41	862000	826,299	0,191	13,868	0,714

The constants of the general shape of the IDF equation (Equation 7) shown in Table 4 were calibrated by this study using the intensity of the maximum precipitation with lengths of 5, 10, 15, 20, 30, 60, 120, 480, 600, 720 and 1.440 min; and return periods of the phenomenon of 2, 5, 10, 20 and 100 years. Therefore, it presented a wide range of application due to the amplitude of intervals, thus this estimate can be used in various hydraulic works.

In general, it becomes possible to note that the proposed equations show typical behavior for the IDF curves, for example, the intensity is indirectly proportional to duration, as noted by Pereira, Silveira and Silvino (2007), while observing that the smaller the duration of the precipitation, the higher the average intensity.

There was a directly proportional relationship between the intensity and the return period, thus showing the difference in the use of Tr for the design of hydraulic structures, once that high return periods indicate a high intensity of precipitation. Thus, the design of more complex water projects requires the provision of hydrological quantities of great magnitude with a time interval of high recurrence so that it is possible to estimate peak flows or precipitations that may occur in a given locality. In this context, the cost of such a project is closely linked to the return period of the occurrence of the phenomenon (Beijo et al., 2005).

While examining the regional coefficients for Equation 7 (TABLE 4), it is clear that the constant "b" of each location, with the exception of 40 are numerically equal. The same aspect was observed for the constant "c", however, this presented such a feature for all 41 regions which had their IDF curves equated. This numerical equality is due to the disaggregation method used in the processing of daily rainfall to rainfall events with shorter durations, which employs identical disaggregation ratios for all historical series.

Thus, it is observed that these regional parameters are functions of the relations of rainfall intensities of different durations. Other research also describes equal regional factors, such as the study performed by Oliveira et al. (2000). These authors observed a fact similar to those described above, since that in their studies they used a methodology close to the one used in this paper for the estimation of heavy rains equations for some locations in the State of Goiás.

Table 5 presents the analysis of residues generated by each IDF equation in estimating the measured and modeled data for the Gumbel distribution, which were used in the process of elaborating this mathematical model of extreme rainfall. It is noted that the fluctuations of the results of the equations do not have a significant magnitude compared to the data used in their estimate, once that the average standard error rate (ASE) ranged from 3,215 to 32.382, in agreement with the values obtained for the normalized mean error (NME), which are in the range -13.359 -5.816%.

Table 5 – Results of the validation analysis of IDF equations

Equation	ASE	NME (%)	MME	r	r²	C.I. (99,5%)
1	7,622	-7,341	1,124	0,995	0,990	-4,020-2,960
2	7,927	-7,286	1,123	0,995	0,990	-3,420-2,090
3	6,326	-6,598	1,113	0,996	0,992	-2,900-1,500
4	5,720	-6,427	1,111	0,996	0,993	-2,940-1,830
5	5,829	-6,436	1,111	0,996	0,993	-2,680-1,420
6	4,614	-6,507	1,112	0,996	0,993	-2,420-1,300
7	5,351	-6,452	1,111	0,996	0,993	-2,370-1,220
8	6,829	-7,435	1,125	0,995	0,990	-2,900-1,830
9	7,383	-6,979	1,119	0,996	0,991	-2,600-1,430
10	7,469	-8,406	1,137	0,994	0,988	-2,950-1,990
11	8,903	-7,723	1,129	0,995	0,989	-1,560-0,560
12	4,235	-6,229	1,107	0,997	0,994	-1,890-0,770
13	4,617	-5,954	1,102	0,997	0,994	-2,600-1,370
14	10,494	-9,073	1,145	0,993	0,986	-2,230-1,090
15	7,839	-7,201	1,122	0,995	0,991	-3,290-1,800
16	5,199	-6,429	1,111	0,996	0,993	-2,400-1,240
17	7,651	-6,655	1,114	0,996	0,992	-3,190-1,690
18	5,942	-6,736	1,115	0,996	0,992	-3,430-2,000
19	3,975	-6,041	1,103	0,997	0,994	-2,880-1,520
20	13,631	-9,656	1,152	0,993	0,985	-5,120-3,980
21	5,866	-7,042	1,120	0,996	0,991	-2,400-1,290
22	5,299	-6,241	1,107	0,997	0,993	-1,970-1,020
23	3,215	-5,861	1,100	0,997	0,995	-2,270-0,920
24	5,824	-6,363	1,109	0,997	0,993	-2,700-1,390
25	5,352	-6,137	1,105	0,997	0,994	-2,210-0,850
26	7,098	-6,855	1,117	0,996	0,992	-2,670-1,420
27	4,774	-6,145	1,106	0,997	0,994	-2,090-1,100
28	11,821	-12,215	1,179	0,991	0,981	-2,460-1,280
29	14,671	-11,420	1,171	0,991	0,982	-5,370-4,490
30	5,138	-6,460	1,111	0,996	0,993	-4,370-3,650
31	32,282	-13,359	1,190	0,990	0,980	-3,290-2,030
32	4,811	-6,247	1,108	0,997	0,993	-3,720-2,440
33	5,359	-6,206	1,107	0,997	0,994	-2,490-1,290
34	4,765	-6,051	1,104	0,997	0,994	-2,490-1,190
35	6,822	-6,483	1,111	0,996	0,993	-3,110-1,620
36	4,906	-6,077	1,104	0,997	0,994	-3,460-1,820
37	6,333	-6,486	1,111	0,996	0,993	-2,330-0,950
38	5,854	-6,467	1,111	0,996	0,993	-2,650-1,410
39	4,491	-6,088	1,104	0,997	0,994	-2,110-0,940
40	6,838	-7,333	1,124	0,995	0,990	-11,600-9,700
41	5,242	-6,304	1,109	0,997	0,993	-2,220-1,170

The negative values found for the NME reveal that the equations proposed by this study tend to inexpressively underestimate the measured data. It is noteworthy that the work of Oliveira et al. (2000) showed average standard errors of approximately 14.4% over the IDF equations of some Goiás locations prepared in their study.

It is also emphasized that the ratios of mean multiplicative errors (MME), which according to Moog and Jirka (1998) are very sensitive to small differences, were close to 1, which demonstrates the lack of significant differences in the results given by the mathematical models compared to the measured data.

It is noteworthy that the equations proposed by this study showed one regression coefficient (Table 5) of the approximately 0.980 to 0.995, thus indicating that 98 to 100% of the intensity data variations are explained by the variations in the duration and return period. Thus, the correlation coefficient (r) of these estimates are in the range of about 1, showing that according to Levin (1977) cited by Elias et al. (2009), that the i_m ratio is perfectly and positively correlated with the other two variables.

When it comes to the Wilcoxon-Mann-Whitney test of hypothesis, it was possible to demonstrate that there are no statistical evidence proving that the data estimated by the equation differ from the measured data once that the lower and upper limits of the confidence intervals contained the value 0, therefore the null hypothesis was not rejected. Thus, it is possible to observe that the extrapolation of data for the period of 100 years in most of the historical series caused no great magnitude distortions that could undermine the estimate of these equations, even when some available data contained maximum return period of less than 10 years.

Thus, it can be stated with 99.5% confidence that the IDF equations proposed in this study are significant for the data used, which confirms the feasibility of the use of these equations for their intended processes.

4. CONCLUSION: FINAL CONSIDERATIONS

This work presents many relevant results as it built the equations of intense rains that may be used as an aid in the design of hydraulic and hydrologic studies.

The study confirms that the proposed equations for estimating the intensity of maximum precipitation are applicable to the regions of the cities of Rondônia, presenting a high degree of correlation with related variables, duration and the return period of the phenomenon. This finding was based in statistical analysis and comparison with literature data, making it possible to verify the high degree of confidence of the IDF curves.

For further studies, we recommended the installation of rainfall stations with the capacity of recording data for rain durations shorter that one day in order to confirm the results obtained in this study, since the data of rainfall shorter than one day was obtained synthetically, thus, it may not accurately match the characteristics of the studied area.

In addition, it is advisable to install rainfall stations in the further north region of Rondônia, since that due to the absence of stations in that region it was not possible to contemplate it as an area of influence by some of the estimated equations.

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Texto submetido à RBClima em 27/11/2015