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Daily rainfall disaggregation for Tocantins State, Brazil

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ABSTRACT

In order to design effective Brazilian hydraulic structures, it is necessary to obtain data relating to short-duration intense rainfall from historical series of daily rainfall. This recurring need can be fulfilled by rainfall disaggregation methodology. The objective of this study was to determine the intense rainfall disaggregation constants for the State of Tocantins and to compare these constants with those obtained for other regions of Brazil. For the modeling of the frequency of intense rainfall of different durations of less than 24 hours, the Gumbel probability distribution (GPD) was employed using rainfall series from 10 locations in Tocantins state. The results showed that the GPD was adequate by the Kolmogorov-Smirnov and Chi-square tests. The disaggregation constants presented low variability values for different return periods (from 10 to 100 years); the values for Tocantins state are: $h_{12h}/h_{24h}=0.93$, $h_{6h}/h_{24h}=0.86$, $h_{4h}/h_{24h}=0.82$, $h_{3h}/h_{24h}=0.78$, $h_{2h}/h_{24h}=0.72$, $h_{1h}/h_{24h}=0.61$, $h_{50min}/h_{1h}=0.92$, $h_{40min}/h_{1h}=0.83$, $h_{30min}/h_{1h}=0.68$, $h_{20min}/h_{30min}=0.76$ e $h_{10min}/h_{30min}=0.46$. The comparison of the results with those from studies developed for other Brazilian regions showed variations of up to -62.30%, allowing us to conclude that the use of local constants is important in the process of rainfall disaggregation.

Keywords: hydrology, precipitation, short-duration intense rainfall.

Desagregação de chuvas diárias para o estado do Tocantins, Brasil

RESUMO

Para o dimensionamento da estrutura hidráulicas do Brasil, é necessário a obtenção de dados de chuvas intensas de curta duração a partir de séries históricas de chuva diária. Esta situação recorrente pode ser atendida pela metodologia de desagregação de chuvas. Objetivou-

se neste trabalho determinar constantes de desagregação de chuvas intensas para o Estado do Tocantins e proceder a comparação destas constantes com aquelas obtidas para outras regiões do Brasil. Para a modelagem da frequência das chuvas intensas de diferentes durações, foi empregada a distribuição de probabilidades Gumbel, tendo sido utilizadas séries pluviográficas de 10 localidades do estado do Tocantins. Os resultados mostraram que a distribuição de probabilidades Gumbel foi considerada adequada pelos testes Kolmogorov-Smirnov e Qui-quadrado. Observou-se que as constantes de desagregação apresentaram valores praticamente invariáveis para tempos de retorno entre 10 e 100 anos, tendo sido obtidas as seguintes constantes médias para o estado do Tocantins: $h_{12h}/h_{24h}=0,93$, $h_{6h}/h_{24h}=0,86$, $h_{4h}/h_{24h}=0,82$, $h_{3h}/h_{24h}=0,78$, $h_{2h}/h_{24h}=0,72$, $h_{1h}/h_{24h}=0,61$, $h_{50min}/h_{1h}=0,92$, $h_{40min}/h_{1h}=0,83$, $h_{30min}/h_{1h}=0,68$, $h_{20min}/h_{30min}=0,76$ e $h_{10min}/h_{30min}=0,46$. A comparação dos resultados com os de estudos desenvolvidos para outras regiões brasileiras mostrou variações de até -62,30%, permitindo se concluir que a utilização de constantes locais é importante no procedimento de desagregação de chuvas.

Palavras-chave: chuvas intensas de curta duração, hidrologia, precipitação.

1. INTRODUCTION

In the planning and management of soil and water resources, it is indispensable to have backgrounds related to the climatic variables, among which heavy rainfall may be highlighted (Souza et al., 2012). However, according to Back (2009), there are some significant problems in obtaining the intensity-duration-frequency relation (IDF) of heavy rainfall with lower durations (< 24 hours) due to the scarcity of rainfall records and to the short-term observed periods.

According to Cardoso et al. (1998) and Oliveira et al. (2000), in order to overcome these problems, it is necessary to estimate short-duration heavy rainfall from daily rainfall records, since the latter are much more available in the Brazilian territory. According to Engida and Esteves (2011), Gyasi-Agyei (2005), Paola et al. (2014) and Yusop et al. (2014), an alternative to circumvent this data limitation is the application of the rainfall disaggregation methodology, which allows the estimation of short-duration heavy rainfall from the annual maximum daily rainfall (h_{day}) monitored by standard rain gauges. In this methodology, the 24-hour intense rainfall (h_{24h}) is initially estimated from h_{day} , as the difference between them relates to the fact that the latter corresponds to the depth observed based on a fixed interval of 24 hours, since the readings are performed daily at the same time (normally 0900 every day), while h_{24h} relates to precipitation monitored during any 24-hour period by means of pluviographs, without fixing the beginning of the initial time (Mello et al., 2001).

For Brazil, there are a few studies related to rainfall disaggregation coefficients determination for a given region (or state). However, it is possible to highlight the studies of Torga (1974) and CETESB (1980). Both estimated average coefficients for Brazil, Back et al. (2012) for Santa Catarina, Teixeira et al. (2011) for Pelotas and ATP-Engenharia e INFRAERO (2010) for Manaus. Many Brazilian states lack detailed studies regarding rainfall disaggregation coefficients, especially for the states of the Northern Brazilian region. Because of this, the pioneer study of CETESB (1980) is still used as a reference for heavy rainfall studies (Silveira, 2000; Mesquita et al., 2009; Garcia et al., 2011; Teodoro et al., 2014).

According to this study, there is a virtually invariant relationship between h_{24h} and h_{day} (h_{24h} / h_{day}), which can be assumed to be equal to 1.14, which means that, on average, h_{24h} is 14% higher than h_{day} . Another important aspect of the CETESB (1980) study is the availability of average disaggregation coefficients for Brazilian territory, which allow for the estimation of heavy rainfall as short as a 5-minute duration of the daily rainfall (h_{day}). Therefore,

an important investigation not yet carried out is the analysis of quantitatively possible errors associated with short-duration heavy rainfall proportioned by disaggregation coefficients generated for a large and heterogeneous region applied to another region which is smaller and has a specific climate. The application of coefficients generated by CETESB (1980) to estimate heavy rainfall in a specific state is a good example of this.

Tocantins State occupies about 277,620 km² and is located in the northern region of Brazil. In the last decades, Tocantins has experienced an intense expansion of agricultural and livestock activities as well as increased population pressure which require scientific investigations to guide its orderly development. Considering the agricultural potential of this state and the damaging effects of the high kinetic energy of heavy rains in rural environments, such knowledge is essential to support soil and water conservation studies. Consideration should also be given to the growth of the State and the need for background data for the design of hydraulic structures such as urban and rural drainage systems and landfills, among others.

In this context, the objective of this study was to determine the intense rainfall disaggregation constants for the Tocantins State from an historical series of 10 rain gauge stations, to analyze the influence of the frequency of the hydrological variable on the values of the disaggregation constants and the acquisition of the following relationships for the State of Tocantins: h_{12h}/h_{24h} , h_{6h}/h_{24h} , h_{4h}/h_{24h} , h_{3h}/h_{24h} , h_{2h}/h_{24h} , h_{1h}/h_{24h} , h_{50min}/h_{1h} , h_{40min}/h_{1h} , h_{30min}/h_{1h} , h_{20min}/h_{30min} and h_{10min}/h_{30min} . Specifically, the objective of this study was to verify whether the average disaggregation constants available for Brazil or available for other Brazilian states are adequate for estimating short-duration heavy rainfall for Tocantins State.

2. MATERIAL AND METHODS

The State of Tocantins is located between parallels 5°10'06" and 13°27'59" south latitude and meridians 45°44'46" and 50°44'33" west longitude, with an area of 277,621 km², representing 3.26% of the total area of Brazil and 7.2% of the northern region. The Amazon biome, characterized by seasonal, open and dense Ombrophylous forests, occupies 9% of the state, while the predominant biome in 91% of the state is the Cerrado, characterized by vegetation formations of savanna and forest structure (IBGE, 2004; Tocantins, 2012).

According to Souza (2016) in Tocantins there are three homogeneous climatic regions, according to the Thornthwaite classification (Figure 1): a) C1s2A'a' - dry sub-humid climate, with high amount excess rain in the summer, mega-thermal; (b) C2wA'a' - sub-humid climate, with moderate water deficiency in the winter, mega-thermal; and c) B1wA'a' - humid climate, with moderate water deficiency in the winter, mega-thermal.

The database used in this study consisted of an historical series of maximum rainfall intensities associated with the durations of 10, 20, 30, 40, 50, 60, 120, 240, 360, 720 and 1440 minutes for 10 rain-gauges, located in the Tocantins State, within the hydro-meteorological network of the Brazilian National Water Agency (ANA), that present pluviographic recordings from 1989 to 1999. Intense rainfall data were acquired for each station. First, the most intense rainfall events were identified for each year. Second, the maximum rain depth for each evaluated rainfall duration and respective average maximum intensity were calculated, according to Silva et al. (2003).

Figure 1 presents the ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) digital elevation model for the State of Tocantins, available from the USGS (United States Geological Survey) website, with a spatial resolution of 30 meters and the location of the rainfall stations used in the study.

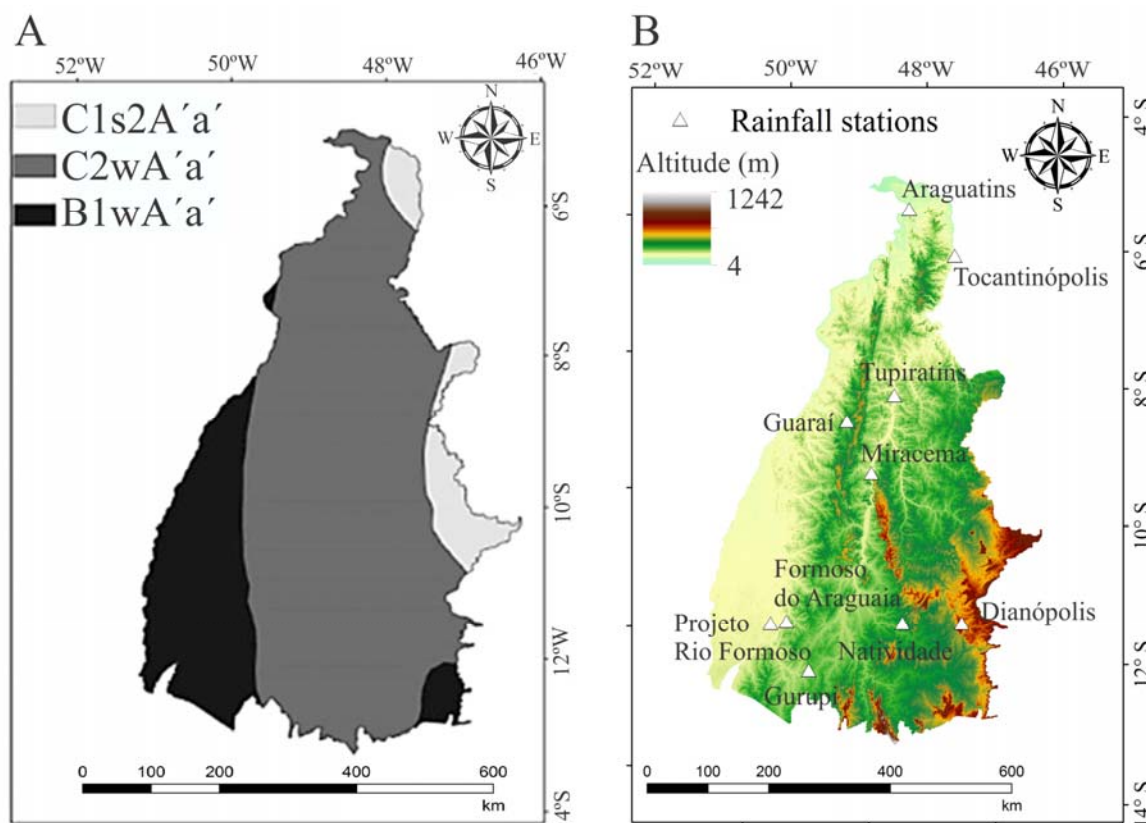


Figure 1. Thornthwaite and Matter climatic classification for the Tocantins State (Souza, 2016) (A); ASTER digital elevation model for the Tocantins State and spatial distribution of the rainfall stations used in the present study (B).

The Gumbel Probability Distribution (GPD) was adjusted to model the frequency of heavy rainfall of different durations in the Tocantins. This distribution has been widely applied to intense rainfall series as these datasets present an asymptotic frequency behavior, with a positive tail. Good results can be highlighted by GPD application as those obtained in the studies of Waylen and Woo (1982), Cardoso et al. (1998), Mello et al. (2001), Coles et al. (2003), Campos et al. (2015), Ferreira et al. (2005), Oliveira et al. (2005), Back (2006), Silva et al. (2003), Damé et al. (2006), Back (2009), Damé et al. (2010), Villarini et al. (2011), Back et al. (2012), Mello and Viola (2013), Borges and Thebaldi (2016) and Caldeira et al. (2015). GPD can be described by Equation 1 (Mello and Silva, 2013).

$$f(x) = \alpha \cdot e^{[-\alpha \cdot (x - \mu) - e^{-\alpha \cdot (x - \mu)}]} \quad (1)$$

where:

- x is the hydrological variable,
- α is the scale parameter, and
- μ is the position parameter of the distribution.

The calculation of these parameters by the method of statistical moments is given by Equations 2 and 3. However, it is important to emphasize that since the pluviographic historical series available in Brazil are mostly short, mainly for the northern region states, the development of studies related to the methods for the estimation of GPD parameters, like Moments-L and Maximum Likelihood, can be necessary, as suggested by Mello and Silva (2013).

$$\alpha = \frac{1,2826}{s} \quad (2)$$

$$\mu = \bar{x} - 0,45 \cdot s \quad (3)$$

where:

\bar{x} and s are the mean and standard deviation of the historical series, respectively.

The integration of Equation 1 provides the cumulative probability function (CPF) (Equation 4).

$$P(X \geq x) = 1 - e^{[-e^{(-\alpha \cdot (x - \mu))}]} \quad (4)$$

The suitability of the GPD was verified by the Kolmogorov-Smirnov and Chi-square tests at a significance level of 5%. The estimation of the hydrological variable associated with a given recurrence (X_{TR}) was obtained by Equation 5.

$$x_{TR} = \frac{-LN[-LN(1 - \frac{1}{TR})]}{\alpha} + \mu \quad (5)$$

where:

TR is the return period, in years.

For the determination of the disaggregation coefficients, the following TR values were considered: 2, 5, 10, 20, 50 and 100 years. Subsequently, for each frequency analyzed, the duration-to-date relationship method was used to obtain the disaggregation constants. According to Tucci (2009), this method considers two aspects: a) the tendency of the probability curves of different durations to remain parallel to each other; and b) for different locations there is a great similarity in the relationships among average maximum precipitations varying according to different durations. The relationships among different durations were obtained according to Equation 6.

$$r_{t1/t2} = \frac{\text{intense rains of duration } t1}{\text{intense rains of duration } t2} \quad (6)$$

where:

$r_{t1/t2}$, is the constant that characterizes the relation between the intense rains of duration t_1 and of duration t_2 .

The following disaggregation coefficients were calculated: h_{12h}/h_{24h} , h_{6h}/h_{24h} , h_{4h}/h_{24h} , h_{3h}/h_{24h} , h_{2h}/h_{24h} , h_{1h}/h_{24h} , h_{50min}/h_{1h} , h_{40min}/h_{1h} , h_{30min}/h_{1h} , h_{20min}/h_{30min} and h_{10min}/h_{30min} for all evaluated return periods. Because the database of the present study does not have the series of annual maximum daily precipitation (h_{day}) for the 10 locations used in this study, it was not possible to obtain the h_{24h}/h_{day} ratio. However, this is not characterized as a limitation for the application of the constants developed herein, since according to CETESB (1980), the h_{24h}/h_{day} ratio presents a quasi-constant value of 1.14.

3. RESULTS AND DISCUSSION

Table 1 presents the maximum errors generated by GPD in the modeling of the frequencies related with maximum rainfall series with duration varying from 10 to 1440 minutes. Since the

statistically null value of the Kolmogorov-Smirnov test for the studied series is 0.391 ($\Delta F_{\text{Tab}(11;0.05)}$), all the 120 adjustments were approved at a 5% probability level. However, based on Chi-Square test, for which the null value for the studied series is 3.845 ($\chi^2_{\text{Tab}(1;0.05)}$), 5 adjustments were approved only when 1% probability level was considered: 20- and 1440-min for Araguatins, 30-min for Dianópolis, 240-min for Guaraí and 180-min for Tocantópolis. Despite of these 5 exceptions, taking the results into account, we can affirm that GPD was adequate for this study.

Table 1. Maximum adjustment error of the Gumbel distribution aiming towards application of the Kolmogorov-Smirnov and Chi-square tests for the maximum rainfall series with durations between 10 and 1440 minutes for 10 locations in the Tocantins State.

Station	Duration of precipitation (min)											
	10	20	30	40	50	60	120	180	240	360	720	1440
Kolmogorov-Smirnov												
Alvorada	0.226	0.097	0.117	0.109	0.099	0.103	0.067	0.111	0.157	0.132	0.157	0.163
Araguatins	0.249	0.249	0.249	0.247	0.243	0.232	0.213	0.255	0.248	0.251	0.301	0.280
Dianópolis	0.183	0.155	0.155	0.243	0.225	0.188	0.160	0.143	0.160	0.132	0.131	0.155
F. do Araguaia	0.235	0.080	0.096	0.104	0.162	0.154	0.189	0.142	0.114	0.081	0.164	0.115
Guaraí	0.163	0.143	0.158	0.187	0.144	0.151	0.142	0.154	0.172	0.151	0.151	0.144
Miracema-TO	0.184	0.133	0.158	0.216	0.157	0.161	0.200	0.222	0.153	0.165	0.166	0.173
Natividade	0.249	0.249	0.249	0.247	0.247	0.244	0.232	0.223	0.206	0.237	0.243	0.243
P. R. Formoso	0.198	0.125	0.147	0.139	0.111	0.127	0.056	0.063	0.107	0.078	0.123	0.106
Tocantópolis	0.186	0.106	0.084	0.120	0.116	0.116	0.056	0.111	0.133	0.122	0.092	0.224
Tupiratins	0.188	0.231	0.220	0.208	0.194	0.189	0.133	0.107	0.152	0.163	0.155	0.183
Chi-Square												
Alvorada	0.074	0.014	0.374	0.156	0.006	0.058	1.597	2.674	3.832	3.132	0.076	0.027
Araguatins	0.594	5.591	0.172	0.321	0.659	1.401	1.079	3.290	2.058	2.190	1.017	4.576
Dianópolis	0.987	0.999	3.894	0.932	0.819	0.971	0.415	0.006	0.746	1.781	1.283	1.709
F. do Araguaia	0.379	0.167	1.184	0.630	0.276	2.790	0.309	1.402	0.028	0.253	1.082	1.558
Guaraí	0.583	0.399	1.147	0.488	0.576	0.337	1.165	1.568	6.376	0.504	0.411	0.441
Miracema-TO	1.961	1.194	0.016	0.229	0.899	0.135	0.725	0.633	1.095	0.915	3.010	0.029
Natividade	2.477	1.777	0.596	0.042	0.091	0.321	0.125	0.301	0.018	0.107	0.016	0.347
P. R. Formoso	0.202	0.168	0.130	0.207	2.004	1.110	0.272	0.082	0.579	0.682	2.136	1.358
Tocantópolis	0.345	0.369	0.143	1.842	0.859	1.146	0.549	4.548	1.404	1.895	0.096	0.321
Tupiratins	1.636	3.007	0.760	0.774	3.587	0.165	0.348	0.095	0.394	0.849	1.034	0.057

Figure 2 shows the disaggregation coefficients of rainfall as a function of the return period. There are differences in the values of the constants for the different locations studied, highlighting the lowest values of the constants h_{12h}/h_{24h} , h_{6h}/h_{24h} and h_{4h}/h_{24h} for Tupiratins. Considering a same station, for return periods greater than 10 years, a quasi-constant value occurs, since the lines become asymptotic at the x-axis. Thus, we calculated the mean constants for each locality considering return periods between 10 and 100 years, following the same procedure used by CETESB (1980).

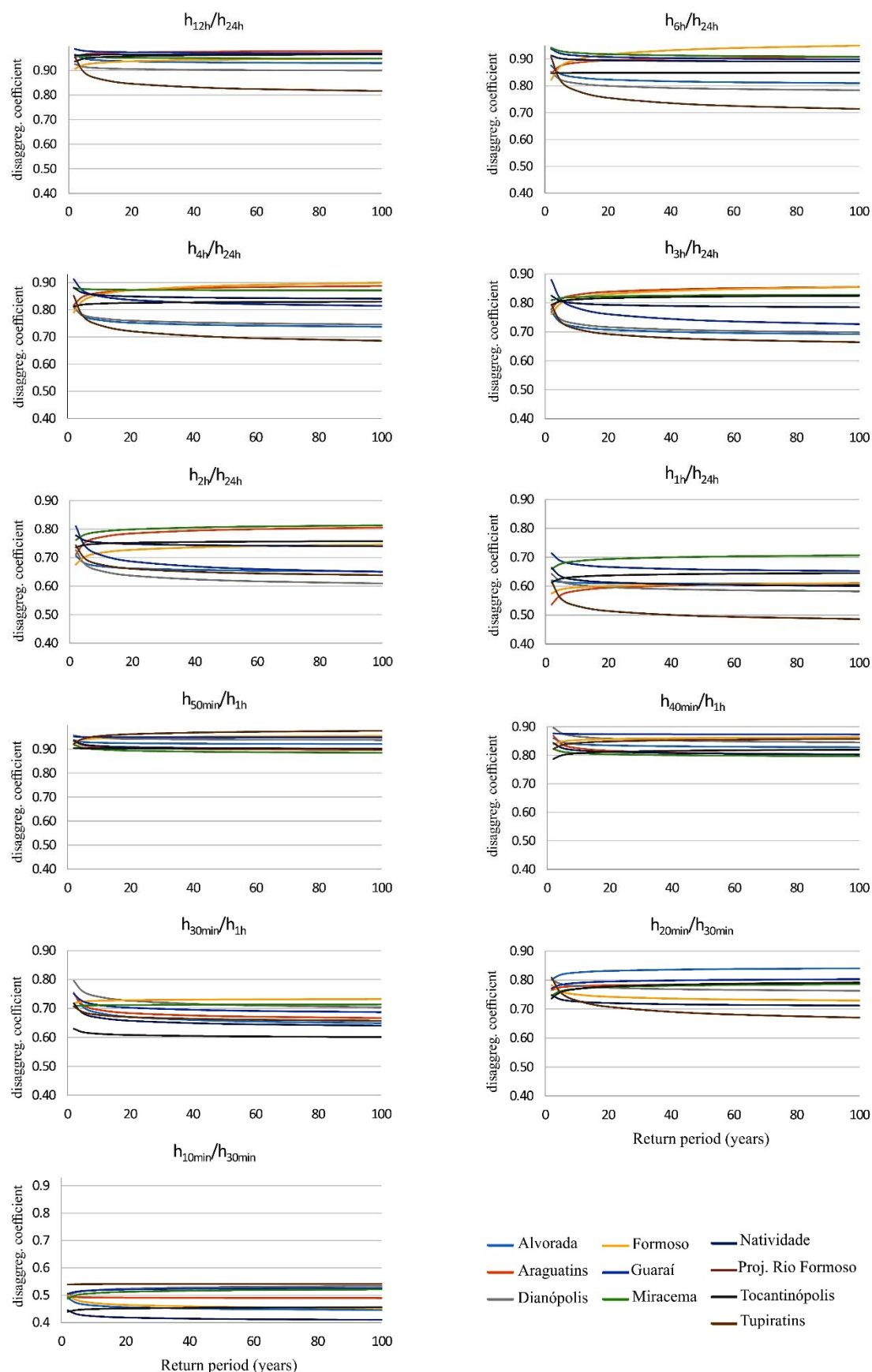


Figure 2. Relationship between disaggregation coefficients and return period for 10 locations in the Tocantins state.

Table 2 presents the mean (x_1) and coefficient of variation (CV_1) for the intense rainfall disaggregation coefficients for return periods from 10 to 100 years, for each of the 10 pluviographic stations employed. CV_1 values are lower than 4.04% in all situations, indicating that there is a reduced variation of the values of the coefficients for return periods between 10 and 100 years. Table 2 also presents the mean values (x_2) of the disaggregation coefficients for Tocantins State and respective coefficients of variation (CV_2). These values correspond to the mean and coefficient of variation for the set of 10 rainfall stations used for each coefficient. In this situation, the reduced variation of the disaggregation coefficients in the Tocantins State can also be highlighted, which means that they can be applied for estimating heavy rainfall with durations of less than 24 hours in Tocantins State.

Another relevant aspect when analyzing the disaggregation coefficients is their non-linear characteristic. It can be observed, for example, that, on average, the 12-hour heavy rainfall equals 93% of the 24-hour depth, or even the intense 10-minute rainfall equals 46% of the 30-minute rainfall.

Table 2. Mean (x_1) and coefficient of variation (CV_1) of the disaggregation coefficients for return period times varying between 10 and 100 years for each studied station, and mean (x_2) and coefficient of variation (CV_2) for each constant in Tocantins State.

Station	h_{12h}/h_{24h}		h_{6h}/h_{24h}		h_{4h}/h_{24h}		h_{3h}/h_{24h}		h_{2h}/h_{24h}		h_{1h}/h_{24h}	
	x_1	CV_1	x_1	CV_1	x_1	CV_1	x_1	CV_1	x_1	CV_1	x_1	CV_1
Alvorada	0.93	0.55	0.82	1.18	0.75	1.45	0.70	1.60	0.66	1.22	0.61	0.30
Araguatins	0.97	0.42	0.90	1.08	0.88	1.28	0.84	1.43	0.79	1.89	0.60	1.95
Dianópolis	0.90	0.48	0.80	1.44	0.76	1.35	0.71	1.82	0.63	3.07	0.59	1.67
F. Araguaia	0.94	0.79	0.93	2.49	0.88	2.25	0.84	2.01	0.73	1.72	0.60	1.03
Guaraí	0.97	0.29	0.91	0.71	0.83	1.91	0.75	3.30	0.68	3.85	0.66	1.49
Miracema	0.95	0.25	0.92	0.69	0.87	0.19	0.82	0.43	0.80	1.21	0.70	1.28
Natividade	0.86	1.00	0.83	1.77	0.81	2.15	0.79	2.10	0.75	2.18	0.57	0.35
P. R. Formoso	0.96	0.07	0.89	0.37	0.85	0.71	0.79	0.75	0.75	0.76	0.61	1.52
Tocantinópolis	0.96	0.54	0.85	0.02	0.83	0.38	0.82	0.69	0.75	0.51	0.64	0.89
Tupiratins	0.84	2.56	0.75	4.04	0.71	3.62	0.69	2.95	0.66	2.50	0.51	3.95
x_2	0.93	-	0.86	-	0.82	-	0.78	-	0.72	-	0.61	-
CV_2	5.13	-	6.91	-	7.18	-	7.53	-	8.36	-	8.54	-

Station	h_{50min}/h_{1h}		h_{40min}/h_{1h}		h_{30min}/h_{1h}		h_{20min}/h_{30min}		h_{10min}/h_{30min}	
	x_1	CV_1	x_1	CV_1	x_1	CV_1	x_1	CV_1	x_1	CV_1
Alvorada	0.92	0.26	0.83	0.57	0.67	2.35	0.83	0.76	0.42	1.71
Araguatins	0.90	0.60	0.81	1.17	0.68	1.82	0.78	0.41	0.46	0.21
Dianópolis	0.94	0.36	0.85	1.06	0.72	2.23	0.77	0.93	0.50	1.39
F. Araguaia	0.95	0.45	0.86	0.49	0.73	0.34	0.74	1.23	0.43	1.98
Guaraí	0.95	0.07	0.87	0.07	0.70	1.55	0.80	0.72	0.49	0.79
Miracema	0.89	0.69	0.80	0.57	0.71	0.15	0.78	0.91	0.48	1.26
Natividade	0.91	0.76	0.82	1.33	0.67	2.17	0.71	2.41	0.50	0.19
P. R. Formoso	0.91	0.60	0.81	0.78	0.65	1.87	0.72	0.86	0.39	1.55
Tocantinópolis	0.90	0.04	0.81	0.68	0.61	0.82	0.78	1.24	0.42	0.69
Tupiratins	0.97	1.01	0.85	0.74	0.67	1.35	0.70	3.72	0.51	0.09
x_2	0.92	-	0.83	-	0.68	-	0.76	-	0.46	-
CV_2	2.76	-	2.96	-	5.40	-	5.60	-	9.16	-

The comparison of the mean disaggregation coefficients obtained in the present study (x_2 , Table 2) with the results of CETESB (1980) for Brazil, Back et al. (2012) for the Santa Catarina coast, Teixeira et al. (2011) for Pelotas and ATP-Engenharia / INFRAERO (2010) for Manaus, is presented in Table 3.

Table 3. Some disaggregation coefficients of intense rainfall obtained for Brazil (C_1) (CETESB, 1980), Santa Catarina coast (C_2) (Back et al., 2012), interior of Santa Catarina (C_3) (Back et al., 2012), Pelotas (C_4) (Teixeira et al., 2011) and Manaus (C_5) (ATP-Engenharia/INFRAERO, 2010), and the respective variation percentage (Δ) in relation to the constants obtained for Tocantins State in the present study.

Constants	1	Δ_1	2	Δ_2	3	Δ_3	4	Δ_4	5	Δ_5
h_{12h}/h_{24h}	0.85	-8.60	0.70	-24.73	0.78	-16.13	0.93	0.00	0.98	5.38
h_{6h}/h_{24h}	0.72	-16.28	0.52	-39.53	0.63	-26.74	0.85	-1.16	0.91	5.81
h_{1h}/h_{24h}	0.42	-31.15	0.23	-62.30	0.38	-37.70	0.48	-21.31	0.55	-9.84
h_{30min}/h_{1h}	0.74	8.82	0.65	-4.41	0.77	13.24	0.69	1.47	-	-
h_{20min}/h_{30min}	0.81	6.58	0.80	5.26	0.81	6.58	-	-	-	-
h_{10min}/h_{30min}	0.54	17.39	0.54	17.39	0.52	13.04	-	-	-	-
h_{10min}/h_{24h}	-	-	-	-	-	-	-	-	0.19	0.00

Comparing the coefficients obtained for Tocantins with those obtained by CETESB (1980) for Brazil as a whole, differences of up to -31.15% (h_{1h}/h_{24h}) are observed. For this particular coefficient, for Tocantins the rainfall of 1h equals 61% of the rainfall of 24h, while the value available for Brazil (CETESB, 1980) is 42%. Analyzing the variations obtained in relation to Santa Catarina and Pelotas, greater differences are observed, with a variation that exceeds 60%. Manaus presents the smallest differences (up to -9.84%), which can be justified by the similarity of the predominant precipitation mechanism, which is majority convective rainfall (Reboita et al., 2010; Viola et al., 2014). When considering the 10-minute rainfall estimate of the 24-hour rainfall, it is observed that the sequential application of the constants h_{1h}/h_{24h} , h_{30min}/h_{1h} and h_{10min}/h_{30min} results in a value of 0.19 (present study), 0.17 (Brasil, CETESB, 1980), 0.08 (Santa Catarina coast, Back et al., 2012), 0.15 (outback Santa Catarina, Back et al., 2012) and 0.05 (Pelotas, Teixeira et al., 2011). Comparing this result to that of Manaus, we can observe the same value (0.19). This result agrees with Back's contention that the methodology of intense rainfall disaggregation has regional validity.

These results show significant differences among the disaggregation coefficients of the northern region (Manaus and Tocantins), southern Brazil (Pelotas, coast and Santa Catarina's outback) and mean coefficient values for entire the country. Thus, it is important to emphasize the recommendations of Back et al. (2012) and CETESB (1980) that is more appropriate to use specific disaggregation coefficients for each site of interest as they present specific climatic factors that can directly affect the temporal behavior of this hydrological variable (short-duration heavy rainfall).

As there are only a few pluviographic series available, mainly for Northern region of Brazil, the disaggregation coefficients calculated to Tocantins State are important tools for supporting intense rainfall equations based on daily rainfall datasets, which, in turn, are much more available. In addition, it is relevant to highlight that, according to Marengo (2001), possible climate changes can affect the frequency of occurrence as well as heavier rainfall events, and thus change the probability structure of the models from a stationary to nonstationary condition, making it necessary update the disaggregation coefficients.

4. CONCLUSIONS

The GPD was adequate based on the Kolmogorov-Smirnov and Chi-square tests to model the frequency of occurrence of intense rainfall with durations of 10 to 1440 minutes of the 10 pluviographic stations of the Tocantins State addressed in the present study.

Disaggregation coefficients are quasi-constant for return periods between 10 and 100 years, which can be concluded based on the reduced coefficient of variation, which was lower than 4.04% in all analyzed situations.

The calculation of mean disaggregation coefficients indicated a coefficient of variation lower than 9.16% for all of them, which allows us to infer that the calculated average values are adequate for the disaggregation of heavy rainfall in Tocantins State.

Comparing the disaggregation coefficients estimated for Tocantins State in this study with others estimated for all of Brazil, as well as with those estimated by other stations/regions with different weather characteristics, differences of up to 60% were obtained.

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