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RAINFALL SEASONALITY AND EROSIVITY FOR TWO AGRO-INDUSTRIAL REGIONS IN BRAZIL

SAZONALIDADE E EROSIVIDADE DA CHUVA PARA DUAS REGIÕES AGROINDUSTRIAIS NO BRASIL

Abstract: The aim of this study was to determine the rainfall erosivity (R), return period and the probability of occurrence of rainfall in Cáceres and Rondonópolis municipalities in the state of Mato Grosso, Brazil. The rainfall erosivity index (EI_{30}) and rainfall coefficient (Rc) were calculated using pluviometric data for the periods of 1968–2009 and 1970–2009 for the stations of Rondonópolis and Cáceres, respectively. Equations were then fit in order to estimate the monthly EI_{30} values from monthly Rc for each station. The study show that EI_{30} values estimated from equations relating rainfall coefficient and erosivity for a particular place, even if obtained from a small series of pluviometric data, are more reliable than the values estimated from equations of nearby locations. The proximity between two locations should not be used as a unique condition to extrapolate the values of EI_{30m} and Rc_m since this proximity is not necessarily related with the similarity of the physical characteristics of rainfalls. The results show good relationship between EI_{30} and Rc, providing, for Cáceres and Rondonópolis, R estimates with high reliability. The stations of Cáceres and Rondonópolis have R average values of 5,579 and 6,904 MJ mm ha^{-1} h^{-1} $year^{-1}$, a return period of 2.1 and 3.7 years, and probability of occurrence of 46.8 and 26.9%, respectively. For both stations, the months with most erosive rainfall are december, january and february, which correspond to 45% (Cáceres) and 52% (Rondonópolis) of the annual erosivity.

Key words: water erosion, pluviograph data, pluviometric data, rainfall coefficient and temporal variability.

Resumo: O objetivo deste estudo foi determinar a erosividade da chuva (R), período de retorno e a probabilidade de ocorrência de chuvas nos municípios de Cáceres e Rondonópolis, estado de Mato Grosso, Brasil. O índice de erosividade da chuva (EI_{30}) e o coeficiente de chuva (Rc) foram calculados usando dados pluviométricos dos períodos de 1968-2009 e 1970-2009 para as estações de Rondonópolis e Cáceres, respectivamente. As equações foram então ajustadas para estimar valores mensais de EI_{30} a partir do Rc mensal, para cada estação. O estudo revelou que os valores de EI_{30} estimados a partir de equações que relacionam o coeficiente de chuva e a erosividade para um determinado lugar, mesmo se obtidos a partir de uma pequena série de dados pluviométricos, são mais confiáveis do que valores estimados a partir de equações desenvolvidas para locais próximos. A proximidade entre dois locais não deve ser usada como a única condição para extrapolar valores de EI_{30m} e Rc_m, uma vez que essa proximidade não está necessariamente relacionada com a similaridade das características físicas das chuvas. Foi observada boa relação entre EI_{30} e Rc, proporcionando, para Cáceres e Rondonópolis, estimativas de R com alta confiabilidade. As estações de Cáceres e Rondonópolis apresentam valores médios de R de 5.579 e 6.904 MJ mm ha^{-1} h^{-1} ano^{-1}, período de retorno de 2,1 e 3,7 anos e probabilidade de ocorrência de 46,8% e 26,9%, respectivamente. Para ambas as estações, os meses com chuvas mais erosivas são dezembro, janeiro e fevereiro, correspondendo a 45% (Cáceres) e 52% (Rondonópolis) da erosividade anual.

Palavras-chave: erosão hídrica, dados pluviográficos, dados pluviométricos, coeficiente de chuva e variabilidade temporal.

INTRODUCTION

The soil erosion process is one the main causes of soil degradation and leads to losses to various economic activities and to the environment, therefore it has been extensively studied in the world. Approximately 26% of the earth surface it is significantly degraded by soil water erosion, which causes negative impacts on agricultural productivity and rural livelihoods (BIRO et al., 2013; GUERRA; SILVA; BOTELHO, 2007; HIGA et al., 2014).

According to Hernani et al. (2002), the annual soil loss in Brazil, in areas occupied by crops and pastures, is approximately of 822.7 million tons. These soil losses correspond to an annual financial impact of 2.93 to 4.24 billion USD. Crop production is the main land-based economic activity of Mato Grosso, occupying 15% of its area. Mato Grosso is responsible for 25% of the total grain harvesting in Brazil. However, the soil erosion in this state has reached alarming levels. Leite et al. (2009) found losses rates from 1.7 to 7 kg of soil per kg of cotton produced in the Campo Verde municipality (Mato Grosso/Brazil). Considering that in Mato Grosso state the annual average cotton productivity is approximately 4,000 kg ha^{-1}, these losses correspond to the soil loss rate of about 6.8 to 28 t ha^{-1} year^{-1}.

The municipalities of Cáceres and Rondonópolis, both located in the state of Mato Grosso, constitute important poles in the agricultural production of the state. Cáceres has one of the largest cattle herds in Brazil, with 1,083,531 heads, while Rondonópolis with 355,349 is more prominent in the crops and agro-industrial sector (IBGE, 2015; SANTOS, 2016). This municipalities also have severe soil degradation by water erosion, due human activities during the last decades, such as deforestation of native vegetation and inappropriate soil and land-use management (ALMEIDA, 2009). In this way, some scientific activity is needed to allow better land-use planning in these regions.

In the 1960s the Universal Soil Loss Equation (USLE) was developed for characterization of areas with high susceptibility the erosive process. This equation consider five factors that have influence in erosive process: rainfall erosivity (R), soil erodibility (K), topographic factor (LS), cover and management factor (C) and support practice factor (P).

For Wischmeier and Smith (1978), the rainfall erosivity is one of the most important factors that influence soil erosion. This factor is expressed as the rainfall capacity to cause soil erosion in a given unprotected area, and it is numerically defined by indexes based on the physical characteristics of the rainfall in a certain region (CABRAL et al., 2005). The rainfall erosivity index, which is the factor EI_{30}, is the product of the raindrop impact kinetic energy and its maximum 30 minutes rainfall intensity.

The soil loss rate in a unprotected area has a high correlation with the EI_{30} index. Marques et al. (1997) found significant correlations between EI_{30} index and soil loss values (ranging from 0.51 to 0.80) for different soil classes. Schick et al. (2014) found that about 79% of soil losses in an experimental plot subjected to natural rainfall, is explained by the accumulated monthly erosivity in erosive events. Martins et al. (2010), in conditions similar to Schick et al. (2014), observed the changes in EI_{30} explain 93% the variations of the soil losses in different soil classes.

The index EI_{30} has been widely studied in Brazil (LOMBARDI NETO, 1977; CASTRO FILHO; CATANEO; BISCAIA, 1982; PEREIRA, 1983; MARGOLIS; SILVA; JACQUES, 1985; CARVALHO, 1987; MORAIS; MUTTI; ELTZ, 1988; BERTOL, 1993; BERTOL, 1994; ROQUE; CARVALHO; PRADO, 2001). However, for the state of Mato Grosso, only two studies were published to obtain the EI_{30} index. One of them by Morais et al. (1991), where they determined the annual average EI_{30} index relative to the stations of Barranquinho and Flechas, in Cáceres, southeastern Mato Grosso, obtaining the R factor value of 8,493 and 7,830 MJ mm ha^{-1} h^{-1} year^{-1}, respectively. The other by Almeida et al. (2011), which determined the R factor value of 8,810 MJ mm ha^{-1} h^{-1} year^{-1}, for a data series of 19 years in Cuiaba city, whose mean value has possibility of occurrence of 42.92% and return period of 2.3 years. The lack of studies in this context is also caused by the absence of available data in appropriate length and resolution for this region in Brazil, therefore it is crucial studies that focus important agro-industrial sites that are affected by soil degradation.

The main limitations for the R factor assessment in Mato Grosso refer to the small size and discontinuity series of pluviograph data that exist in most stations. This makes the characterization of R factor not feasible since the data is not sufficient to represent the cyclical variation of the climatic parameters. In accordance with Wischmeier and Smith (1978), at least 20 years of information is required to obtain one representative value of rainfall erosivity for a given location. Due to the scarcity of information of the pluviograph stations in Brazil, many researchers (PETKOVŠEK; MIKOŠ, 2004; SILVA, 2004; MELLO et al., 2007; MONTEBELLER et al., 2007; MEN; YU; XU. 2008; ALMEIDA, 2009; SILVA et al., 2010; ARAI et al., 2010) have used the relationship between EI_{30} (determined in detailed pluviograph records) and pluviometric data (monthly precipitation and rainfall coefficient), thus allowing estimate the rainfall erosivity from pluviometric data. This data type is usually more available, found in longer series and with lower discontinuity.

In this context, the aim of this study was to determine the rainfall erosivity (R Factor) from available pluviometric data for the cities of Rondonópolis and Cáceres, its return period, probability of occurrence and its annual, seasonal and monthly distribution, as well as: a) to describe the relationship mathematically among the monthly EI_{30} values, obtained from pluviograph data and precipitation values, and the monthly rainfall coefficients; and b) to compare the estimates of the EI_{30} values obtained from adjusted equations within this study with those used for the Midwest region in mapping the rainfall erosivity of Brazil (SILVA, 2004).

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MATERIALS AND METHODS

Pluviometric data from stations of Cáceres (Code 83405) and Rondonópolis (Code 83410), located in Mato Grosso state, were obtained from the 9th District of Meteorology of the National Agency of Meteorology (INMET) and National Water Agency (ANA). The description of both stations and the series of data used are presented in Table 1. The spatial distribution of the locations studied in this work is presented in Fig. 1, as well as those locations considered in the work of Morais et al. (1991). The regional climate is Tropical Warm Sub-humid (Awi), according to Köeppen's classification, with a predominance of two well defined seasons, rainy season (october to march) and dry season (april to september), with annual precipitation ranging from 1,000 to 1,800 mm.

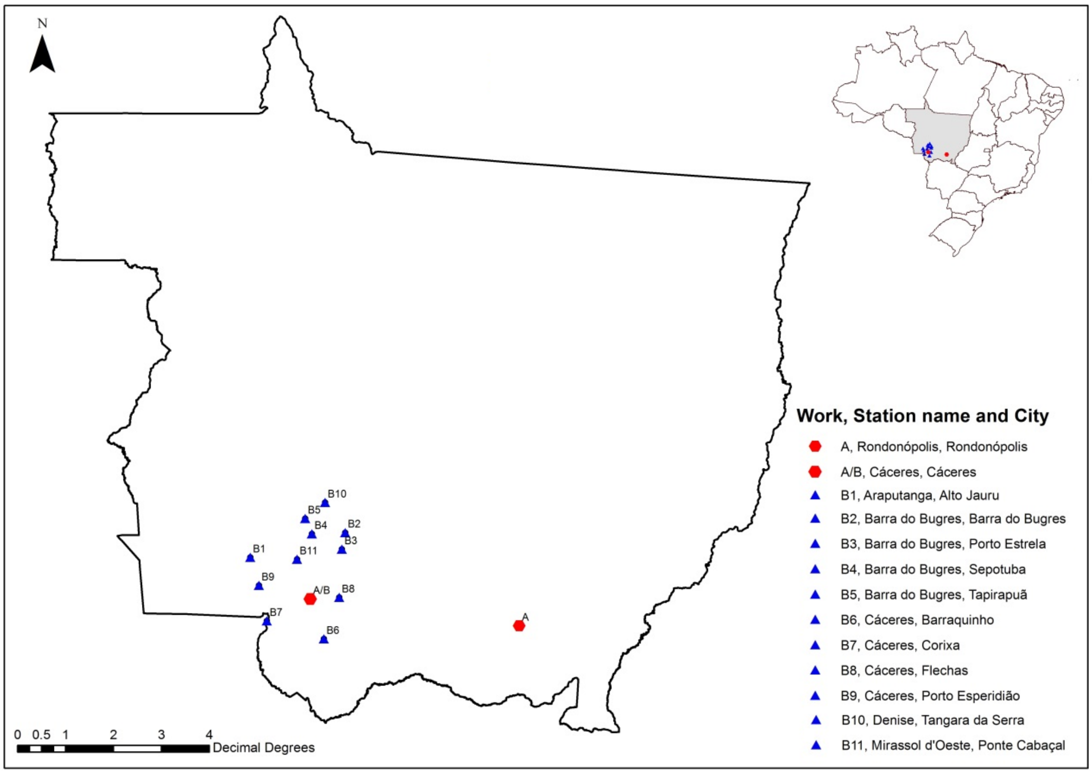

Fig. 1 – Spatial distribution of meteorological stations, in the state of Mato Grosso, used in this study (A) and used by Morais et al. (1991) (B).

Table 1 – Latitude, longitude, altitude, number of erosive rainfalls and, period of pluviograph and pluviometric data from meteorological stations used in this study

Informations	Rondonópolis (Cod 83405)	Cáceres (Cod 83410)
Latitude	16° 27'00" S	16° 03'00" S
Longitude	54° 34' 12"O	57° 40'48" O
Altitude	284 m	118 m
Pluviograph data	1992; 1993; 1995; 1998; 1999; 2005	1992 to 1995; 1997 to 1999; 2001; 2003
Pluviometric data	1968 to 1988; 1993 to 2009	1970 to 1985; 1993 to 2009
Number of erosive rainfalls *	297	315
Mean number of erosive rainfalls	50	32

* according to Wischmeier and Smith (1959) and modified by Cabeda (1976)

To selection of the erosive and individual rainfall events were utilized criteria suggested by Wischmeier and Smith (1958) and modified by Cabeda (1976). This method considers individual rains as those separated from previous and subsequent rain events over a period of at least 6 hours with less than 1 mm of precipitation and, erosive rains those events with precipitation greater than 10 mm or, precipitation greater or equal to 6 mm and duration of 15 min.

The monthly, annual and mean rainfall erosivity were calculated by the EI_{30} index (WISCHMEIER; SMITH, 1958), where the EI_{30} is the product of total kinetic energy of rainfall (E, in MJ ha^{-1}) and the maximum 30 minutes intensity (I_{30}, in mm h^{-1}). The kinetic energy of rainfalls was determined according to Wischmeier and Smith (1958) (Eq. 1), adjusted to the International Unit System by Foster et al. (1981).

$$KE = 0.119 + 0.0873 \times \log Ip \tag{1}$$

where: KE is the kinetic energy for intensities lower than 76 mm h^{-1}, in MJ ha^{-1} mm^{-1}, and Ip is the precipitation intensity of rainfall, in mm h^{-1}.

For intensities greater than or equal to 76 mm h^{-1} the KE value is constant and equal to 0.283 MJ ha^{-1} mm^{-1}, as defined by Wishmeier and Smith (1978) and described in Lombardi Neto and Moldenhauer (1992).

The kinetic energy accumulated from each segment of five minutes of the rainfall chart of an individual erosive rainfall was obtained applying the Eq. 2.

$$KE_s = KE \times h \tag{2}$$

where: KE_s is the kinetic energy in the segment of rainfall, in MJ ha^{-1}, and h is the amount of rainfall in a uniform segment (5 min), in mm.

The total kinetic energy (KE_t) of the individual erosive rainfall was obtained by the sum of the kinetic energy of each segment of the rainfall, whereas the maximum 30 min intensity was obtained from the Eq. 3:

$$I30 = \frac{\sum_{i=1}^{n} i_{ni} \times t_{ni}}{30} \tag{3}$$

where: I30 is the maximum 30 minutes intensity (mm h^{-1}); i_n is the value of the intensity of rainfall in n order (mm h^{-1}), that occurred within a period of 30 minutes; t_n is the occurrence time of the rainfall intensity in n order, that occurred within a period of 30 minutes.

The erosivity index (EI_{30}) was obtained with Eq. 4. This index is obtained with pluviograph data, and was calculate for each individual erosive rainfall that occurred on Rondonópolis and Cáceres on years shows in Table 1.

$$EI30 = KE_t \times I30 \tag{4}$$

where: EI_{30} is the erosivity index of the individual erosive rainfall, MJ mm ha^{-1} h^{-1}.

The rainfall coefficient (Rc) was obtained from Eq. 5, according to Lombardi Neto and Moldenhauer (1992). This coefficient is obtained with pluviometric data, and was calculate for Rondonópolis and Cáceres on periods shows in Table 1.

$$Rc = {PPT_m}^2 / P_a \tag{5}$$

where: R_c is the rainfall coefficient (mm); PPT_m is the mean monthly precipitation (mm) and P_a is the mean annual precipitation (mm).

Five regression models (linear, potential, exponential, quadratic and logarithmic) were used for the average of monthly erosivity indexes and monthly rainfall coefficient for every year that both pluviograph and pluviometric information. The models that had, in the analysis of variance, significance for both regression's and model's parameters and best coefficient of determination (R^2) are highlighted in this work. The last year of the pluviograph data series from both stations (2003 for Cáceres and 2005 for Rondonópolis) was removed from this regression analysis, being used only in the performance evaluation process of the adjusted model and chosen to estimate the EI_{30} values from pluviometric data.

With the Rc values for both stations of this study, the EI_{30} index and R factor were estimated using the adjusted equations in this study and the Eqs. 6 and 7 obtained for the stations of Barranquinhos and Flechas, respectively, which were used as based to estimate the R Factor for the Midwest region in the rainfall erosivity mapping in Brazil (Silva 2004).

$$EI30_m = 56.115 \times {Rc_m}^{0.9504} \tag{6}$$

$$EI30_m = 36.849 \times {Rc_m}^{1.0852} \tag{7}$$

In the analysis of probability of occurrence and return period of the EI_{30} index determined in this study, were used the logarithmic probability law and the theory of extreme values proposed by Schwab et al. (1981). The return period and probability of occurrence were obtained from the Eq. 8 and 9, respectively, described in Mazurana et al. (2009) and Martins et al. (2010).

$$TR = \frac{m}{(N+1)} \tag{8}$$

$$Pr = \frac{100}{TR} \tag{9}$$

where: TR is the return period, in years, in which the rainfall erosivity index will be equaled or exceeded; N is the number of years of record (series' size); m is the number of

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erosivity index when the series of erosivity data is placed in descending order of magnitude; and Pr is the probability of occurrence, in %.

After that, the probability distribution model of Gumbel was fit in order to calculate the annual maximum erosivity through Eqs. 10, 11 and 12, according to Pinto (1996):

$$Y_{TR} = -\ln\left[-\ln\left(1 - \frac{1}{TR}\right)\right] \tag{10}$$

$$K_{TR} = -0.45 + 0.78 \times Y_{TR} \tag{11}$$

$$X_{TR} = \overline{X} + S \times K_{TR} \tag{12}$$

where: Y_{TR} is the reduced variable of Gumbel; TR is the return period (years); K_{TR} is the frequency factor (dimensionless); X_{TR} is the maximum erosivity (annual and monthly) for a given TR (MJ mm ha^{-1} h^{-1} $year^{-1}$); $\overline{X}$ is the average of annual or monthly maximum erosivity (MJ mm ha^{-1} h^{-1} $year^{-1}$); and S is the standard deviation from the maximum erosivity data (MJ mm ha^{-1} h^{-1} $year^{-1}$). These equations allow the use of a population data and not only from one sample, simplifying this way the distribution equations of Gumbel.

The Kolmogorov-Smirnov test was performed to verify the suitability of the distribution of Gumbel for probabilistic representation of the data. The values of observed erosivity indexes were plotted in logarithmic scale, where these values can be related to a desired return period by reading the distribution curve of probability or by applying the equation of theoretical values.

RESULTS AND DISCUSSION

Tables 2 and 3 show the monthly and annual values of precipitation, rainfall erosivity index and rainfall coefficient obtained from the analysis of pluviograph data from the cities of Cáceres and Rondonópolis.

Table 2. Monthly and annual distribution of precipitation (PPT, mm), rainfall erosivity index (EI_{30}, MJ mm [ha h]$^{-1}$), monthly rainfall coefficient (Rc_m) and its respective statistic parameters (mean, ME; standard deviation, SD; mean standard error, MSE; variation coefficient, CV; and correlation coefficient with EI_{30}, r) for the city of Cáceres, MT (1992-1995; 1997-1999; 2001, 2003)

Year	Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1992	PPT	130.50	163.60	187.70	241.50	13.60	0.00	3.20	30.50	109.80	40.90	164.50	190.10	1275.9
	EI_{30}	417	374	549	952	30	0	4	47	376	73	618	601	4038
	Rc_m	13.35	20.98	27.61	45.71	0.14	0.00	0.01	0.73	9.45	1.31	21.21	28.32	14.07
1993	PPT	137.87	111.80	119.00	95.44	25.50	12.30	0.40	6.20	2.80	130.19	70.40	282.77	994.66
	EI_{30}	499	451	571	362	22	26	0	3	1	620	252	1421	4228
	Rc_m	19.11	12.57	14.24	9.16	0.65	0.15	0.00	0.04	0.01	17.04	4.98	80.39	13.19
1994	PPT	95.65	181.61	68.75	41.80	102.00	33.70	11.40	0.00	37.10	121.65	135.74	207.00	1036.4
	EI_{30}	599	1301	300	86	456	58	24	0	176	574	582	1350	5509
	Rc_m	8.83	31.82	4.56	1.69	10.04	1.10	0.13	0.00	1.33	14.28	17.78	41.34	11.07
1995	PPT	116.00	289.20	197.50	59.20	89.50	92.96	3.50	18.10	97.20	81.72	91.70	278.89	1415.4
	EI_{30}	450	1019	507	121	446	361	5	27	295	514	185	1082	5013
	Rc_m	9.51	59.09	27.56	2.48	5.66	6.11	0.01	0.23	6.67	4.72	5.94	54.95	15.24
1997	PPT	237.00	164.89	99.30	77.47	23.20	61.90	0.00	0.00	53.30	87.70	139.10	236.13	1179.9
	EI_{30}	1059	740	584	277	66	260	0	0	385	510	659	1177	5718
	Rc_m	47.60	23.04	8.36	5.09	0.46	3.25	0.00	0.00	2.41	6.52	16.40	47.25	13.36
1998	PPT	112.80	154.40	186.07	78.35	10.20	0.00	0.00	1.70	105.38	200.94	189.80	178.40	1218.0
	EI_{30}	423	1040	722	288	25	0	0	0	383	981	1058	1301	6219
	Rc_m	10.45	19.57	28.42	5.04	0.09	0.00	0.00	0.00	9.12	33.15	29.58	26.13	13.46
1999	PPT	116.20	68.70	162.59	113.84	40.25	1.60	1.00	0.00	7.20	36.60	167.10	357.67	1072.7
	EI_{30}	437	286	644	526	152	0	0	0	5	118	814	1688	4672
	Rc_m	12.59	4.40	24.64	12.08	1.51	0.00	0.00	0.00	0.05	1.25	26.03	119.25	16.82
2001	PPT	275.50	147.80	105.81	73.64	28.60	51.20	0.00	18.60	88.88	97.40	115.20	202.00	1204.6
	EI_{30}	862	609	411	382	66	112	0	43	347	378	458	848	4517
	Rc_m	63.01	18.13	9.29	4.50	0.68	2.18	0.00	0.29	6.56	7.88	11.02	33.87	13.12
2003	PPT	137.87	201.98	336.63	77.70	29.40	32.38	0..00	58.30	38.10	74.20	148.12	192.20	1326.8
	EI_{30}	499	839	1511	261	108	91	0	260	81	200	615	1125	5590

	Rc_m	14.33	30.74	85.40	4.55	0.65	0.79	0.00	2.56	1.09	4.15	16.53	27.84	15.72
ME	PPT	151.04	164.89	162.59	95.44	40.25	31.78	2.17	14.82	59.97	96.81	135.74	236.13	1191.6
	EI_{30}	583	740	644	362	152	101	4	42	228	441	582	1177	5056
	Rc_m	22.09	24.48	25.56	10.03	2.21	1.51	0.02	0.43	4.08	10.03	16.61	51.04	14.01
SD	PPT	61.87	60.81	79.55	58.38	32.81	32.29	3.73	19.58	41.63	50.18	37.96	59.34	138.53
	EI_{30}	226.65	341.53	347.69	258.0	174.46	128.05	7.87	83.93	163.86	285.75	267.07	319.71	745.23
	Rc_m	19.46	15.47	24.31	13.76	3.40	2.06	0.04	0.84	3.86	10.21	8.37	30.84	1.70
MSE	PPT	20.62	20.27	26.52	19.46	10.94	10.76	1.24	6.53	13.88	16.73	12.65	19.78	46.18
	EI_{30}	76	114	116	86	58	43	3	28	55	95	89	107	248
	Rc_m	6.49	5.16	8.10	4.59	1.13	0.69	0.01	0.28	1.29	3.40	2.79	10.28	0.57
CV	PPT	40.96	36.88	48.93	61.17	81.52	101.60	172.20	132.09	69.42	51.84	27.97	25.13	11.63
	EI_{30}	39	46	54	71	115	127	215	199	72	65	46	27	15
	Rc_m	88.12	63.19	95.09	137.13	154.15	136.65	256.32	195.20	94.68	101.80	50.37	60.42	12.15
r	PPT	0.86	0.64	0.90	0.97	0.99	0.96	0.99	0.93	0.89	0.95	0.94	0.64	0.89
	Rc_m	0.87	0.65	0.95	0.94	0.94	0.98	0.99	0.99	0.83	0.91	0.97	0.72	0.90

Table 3. Monthly and annual distribution of precipitation (PPT. mm). rainfall erosivity index (EI_{30}.MJ mm [ha h]$^{-1}$). monthly rainfall coefficient (Rc_m) and its respectives statistic parameters (mean, ME; standard deviation, SD; mean standard error, MSE; variation coefficient, CV; and correlation coefficient with EI_{30}, r) for the city of Rondonópolis. MT (1992; 1993; 1995; 1998; 1999; 2005)

Year	Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1992	PPT	167.26	133.99	135.10	118.93	48.50	30.42	0.00	13.10	88.60	112.90	100.08	255.15	1204.0
	EI_{30}	816	840	892	638	299	213	0	11	149	643	559	1547	6606
	Rc_m	23.24	14.91	15.16	11.75	1.95	0.77	0.00	0.14	6.52	10.59	8.32	54.07	12.28
1993	PPT	115.52	218.96	39.10	208.80	62.25	45.42	0.00	2.15	25.80	147.60	98.89	190.13	1154.6
	EI_{30}	745	708	171	1290	179	271	0	0	136	881	631	1160	6172
	Rc_m	11.56	41.52	1.32	37.76	3.36	1.79	0.00	0.00	0.58	18.87	8.47	31.31	13.04
1995	PPT	240.19	129.03	163.60	240.19	147.70	36.95	0.00	0.00	30.90	116.50	110.86	314.09	1530.0
	EI_{30}	1163	616	858	1260	716	179	0	0	91	669	537	1646	7736
	Rc_m	37.71	10.88	17.49	37.71	14.26	0.89	0.00	0.00	0.62	8.87	8.03	64.48	16.75
1998	PPT	246.20	129.03	191.49	82.07	12.40	0.00	0.00	13.68	54.80	164.14	27.36	287.24	1208.4
	EI_{30}	988	616	850	343	20	0	0	57	182	681	113	1191	5040
	Rc_m	50.16	13.78	30.35	5.57	0.13	0.00	0.00	0.15	2.49	22.29	0.62	68.28	16.15
1999	PPT	304.33	69.17	290.49	16.60	0.00	27.00	0.00	0.00	40.00	59.90	166.00	324.30	1297.8
	EI_{30}	1817	413	1734	48	0	309	0	0	210	132	991	1936	7590
	Rc_m	71.36	3.69	65.02	0.21	0.00	0.56	0.00	0.00	1.23	2.76	21.23	81.04	20.59
2005	PPT	327.50	94.00	136.10	47.00	13.90	27.30	0.00	0.00	37.77	176.10	97.30	295.60	1252.6
	EI_{30}	1752	503	728	251	74	146	0	0	202	942	521	1581	6701
	Rc_m	85.63	7.05	14.79	1.76	0.15	0.60	0.00	0.00	1.14	24.76	7.56	69.76	17.77
ME	PPT	233.50	129.03	159.31	118.93	47.46	27.85	0.00	4.82	46.31	129.52	100.08	277.75	1274.6
	EI_{30}	1214	616	872	638	215	186	0	11	162	658	559	1510	6641
	Rc_m	46.61	15.31	24.02	15.79	3.31	0.77	0.00	0.05	2.10	14.69	9.04	61.49	16.10
SD	PPT	80.46	50.84	82.26	89.20	54.55	15.33	0.00	6.69	22.94	42.40	44.18	49.16	134.18
	EI_{30}	466	150	501	529	270	109	0	23	45	286	280	293	989
	Rc_m	28.29	13.51	22.10	17.46	5.53	0.59	0.00	0.07	2.27	8.60	6.69	17.16	3.08
MS	PPT	32.85	20.75	33.58	36.42	22.27	6.26	0.00	2.73	9.37	17.31	18.04	20.07	54.78
	EI_{30}	190.18	61.27	204.63	215.78	110.07	44.47	0.00	9.31	18.43	116.61	114.40	119.81	403.63
	Rc_m	11.55	5.51	9.02	7.13	2.26	0.24	0.00	0.03	0.93	3.51	2.73	7.00	1.26
CV	PPT	34.46	39.40	51.64	75.00	114.93	55.04	0.00	138.78	49.54	32.73	44.14	17.70	10.53
	EI_{30}	38.39	24.36	57.47	82.80	125.60	58.46	0.00	201.18	27.92	43.41	50.16	19.43	14.89
	Rc_m	60.69	88.26	92.01	110.53	167.10	76.35	0.00	155.06	108.48	58.53	73.98	27.90	19.11
r	PPT	0.92	0.67	0.97	0.99	0.97	0.79	0.00	0.78	0.12	0.90	0.98	0.73	0.80
	Rc_m	0.93	0.65	0.95	0.99	0.96	0.66	0.00	0.80	0.30	0.83	0.97	0.69	0.79

ME – mean; SD – standard deviation; MSE – mean standard error; CV – variation coefficient; r – correlation coefficient with EI_{30}.

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Although the series of pluviograph data analyzed are relatively short, we can observe that both cities have similar rainfall regime, with rainfalls concentrated between the months of december and march, with approximately 61 to 63% of the total precipitation and erosivity, respectively. In Cáceres on average approximately 34% of annual total precipitation and 38% of total erosivity was observed in the two rainiest months of the year (february and december). In Rondonópolis, the two rainiest months (january and december) were responsible for 40% of total precipitation and 41% of annual total erosivity.

We can verify in Tables 2 and 3 that both cities have high correlation (r) and significance ($p \leq 0.01$) among the monthly erosivity index (EI_{30}m), the monthly precipitation (PPT_m) and the monthly rainfall coefficient (Rc_m). The higher values of r are in the wet season (october to march), except for the months of february and december, which were less than 0.75 for both parameters (Rc_m and PPT_m) to both places (Table 2 and 3). This shows the possibility of mathematically describing the relationship among PPT_m, Rc_m and EI_{30} to estimate the EI_{30} from the pluviometric data, in accordance with Lombardi and Moldenhauer (1992).

Considering the limitations of size and the discontinuity of the pluviograph data from both locations in this study (Table 1), high correlation between the EI_{30m} with the PPT_m and Rc_m (Tables 2 and 3), and the availability of pluviometric data with longer series and less discontinuity, equations of regression were adjusted for obtention of EI_{30m} from PPT_m and Rc_m values. The better equations were obtained using the potential model. The equations for Cáceres anda Rondonópolis are expressed in Eqs. 13 and 14, respectively. Both equations presented high coefficients of determination ($R^2 > 0.90$) and significant adjustment parameters ($p \leq 0.01$).

$$EI30_m = 142.1953 \text{ x } Rc_m^{\ 0.5261} \qquad R^2 = 0.91 \qquad (13)$$

$$EI30_m = 171.6612 \text{ x } Rc_m^{\ 0.5240} \qquad R^2 = 0.95 \qquad (14)$$

The Fig. 2 shows the relationship between the average monthly erosivity indexes (EI_{30m}), determined by analysis of rainfall chart (observed), and estimated from equations 13 and 14 considering the Rc data of 2003 (Cáceres) and 2005 (Rondonópolis), which were not used in the regression. The findings show that the adjust of the estimated and observed data, for both cities in this study, presented high coefficients of determination (Cáceres, $R^2 = 0.95$; and Rondonópolis, $R^2 = 0.99$), adjustment parameters significant ($p < 0.001$) and values of angular coefficients close to unit. For these two locations, it is possible to use these equations to estimate the monthly EI_{30} as well as the R factor from pluviometric data, making possible to work with longer and less discontinuous data series (pluviometric data).

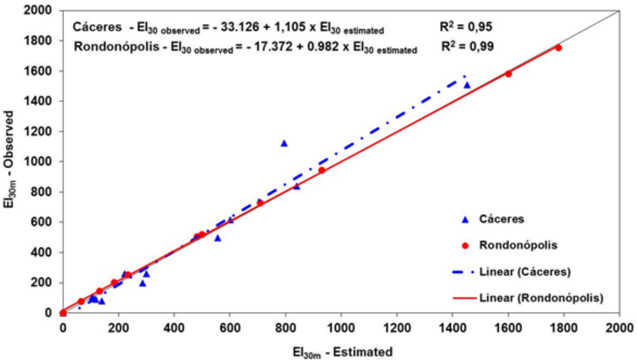

Fig. 2. Relationship between the average of monthly erosivity (EI_{30m}) determined by analysis of rainfall chart (observed) and estimated from pluviometric data (Rc) in the cities of Caceres and Rondonopolis for the year of 2003 and 2005, respectively.

These results confirm those found in literature. In the most recent findings, there are the results from Peñalva-Bazzana, Eltz e Cassol (2007), who obtained a significant linear correlation (EI_{30} = -47.35 + 82.72 Rc) with a high coefficient of determination ($R^2 = 0.84$) in Quarai, RS; and from Almeida et al. (2011), who found a potential relationship (EI_{30} = 109.412 x 0.744Rc) with a high coefficient of determination ($R^2 = 0.91$) in Cuiaba, MT. However, these results are contrary to the results from Mazurana et al. (2010) for the region of Santa Rosa, RS, who obtained both the linear relationship (EI_{30} = 354.71 + 44.927 Rc) and the potential relationship (EI_{30} = 118,52 0.8034Rc) between the EI_{30}m and Rcm indexes, low coefficient of determination ($R^2 = 0.41$ and $R^2 = 0.51$, respectively). In a watershed in Slovenia Petkovšek and Mikoš, (2004) obtained equations for estimating EI_{30} as a function rainfall daily data, with R^2 of 0.879, indicating that in addition to Rc, daily precipitation data also present good precision in the estimation of rain erosivity.

Table 4 shows the values of both EI_{30} index and R factor from analysis of pluviograph data and estimated by Eqs. 6, 7, 13 and 14 with respective errors of estimates for the locations in this study. We observed that the estimates obtained by Eqs. 6 and 7 presented high monthly relative errors (RE) for Cáceres as well as for Rondonópolis, resulting in monthly mean relative error (MRE) ranging from 44 to 61%, being the MRE higher when the same is calculated based just on the most erosive month of the year. This is the month with values of EI_{30} greater than 500 MJ Mm (ha h) $^{-1}$, according to Rufino (1986). Even in annual base Peñalva-Bazzana, Eltz e Cassol (2007), Almeida (2009), Almeida et al. (2011) and Mazurana et al. (2010) have shown low values of RE. The Eqs. 6 and 7 also did not present reliable estimates, with RE higher than 47%.

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Table 4. Monthly (EI_{30m}) and annual (EI_{30a}) erosivity indexes for the cities of Cáceres (2003) and Rondonópolis (2005) obtained from the analysis of rainfall charts, obtained from estimated made by adjusted equations in this study and obtained from equations of stations of Barranquinhos and Flechas (MORAIS et al., 1991)

Month	AP	Estimated EQ6			Estimated EQ7			Estimated EQT		
	EI_{30}	EI_{30}	RE	MRE	EI_{30}	RE	MRE	EI_{30}	RE	MRE
Cáceres										
Jan	498.7	704.4	41.25	43.63[1]	662.3	32.80	55.26[1]	576.9	15.68	21.49[1]
Feb	839.2	1.455.6	73.46	63.63[2]	1.516.9	80.76	72.94[2]	862.2	2.74	9.81[2]
Mar	1.510.5	3.843.6	154.46	29.34[3]	4.596.8	204.32	42.63[3]	1.475.8	2.30	29.83[3]
Apr	260.8	236.8	9.20		190.8	26.86		315.5	20.97	
May	107.9	37.3	65.40		23.1	78.55		113.5	5.17	
Jun	90.8	44.9	50.61		28.5	68.58		125.6	38.30	
Jul	0.0	0.0	0.00		0.0	0.00		0.0	0.00	
Aug	260.3	137.2	47.29		102.3	60.71		233.2	10.39	
Sep	81.0	61.1	24.58		40.6	49.87		149.1	83.96	
Oct	200.3	217.0	8.30		172.6	13.85		300.6	50.04	
Nov	615.4	807.3	31.18		773.8	25.73		622.1	1.09	
Dec	1.124.5	1.324.7	17.80		1.362.0	21.12		818.3	27.23	
Annual	5.589.6	8.870.0	58.69		9.469.7	69.42		5.593.0	0.06	
Rondonópolis										
Jan	1.752.1	3.853.4	119.93	49.62[1]	4610.0	163.11	61.33[1]	1767.5	0.88	4.78[1]
Feb	502.9	359.3	28.56	50.23[2]	307.0	38.95	67.50[2]	477.8	4.99	2.74[2]
Mar	728.1	726.0	0.29	49.01[3]	685.5	5.85	55.17[3]	704.2	3.28	6.82[3]
Apr	251.5	96.2	61.74		68.2	72.88		231.1	8.10	
May	74.4	9.5	87.23		4.8	93.48		64.5	13.32	
Jun	146.1	34.3	76.54		21.0	85.64		130.8	10.46	
Jul	0.0	0.0	0.00		0.0	0.00		0.0	0.00	
Aug	0.0	0.0	0.00		0.0	0.00		0.0	0.00	
Sep	202.1	63.5	68.58		42.4	79.00		183.8	9.06	
Oct	942.1	1184.9	25.76		1.199.2	27.28		922.5	2.08	
Nov	520.6	383.6	26.30		330.9	36.43		495.4	4.83	
Dec	1.581.5	3.171.3	100.53		3.690.7	133.37		1.587.5	0.38	
Annual	6.701.2	9.882.0	47.47		10.959.8	63.55		6.565.1	2.03	

AP - value of EI_{30} determined from the analysis of rainfall charts; Estimated EQ6 and Estimated EQ7 - value of EI_{30} estimated from the rainfall coefficient using the equations 6 and 7. respectively; Estimated EQT -value of EI_{30} estimated from the rainfall coefficient using the equation 13 (Cáceres) and 14 (Rondonópolis); EI_{30} - rainfall erosivity index (EI_{30a} - MJ mm ha^{-1} h^{-1} $year^{-1}$ and EI_{30m} - MJ mm ha^{-1} h^{-1} $month^{-1}$); RE - relative error (%); MRE -mean relative error (%); [1. 2 and 3] MRE considering the 12 month of the year, the most and least erosive month, respectively.

1

These results show that both the extrapolation of the EI_{30} values and the relationship between EI_{30m} and Rc_m for the locations not obtained is not recommended since there are high values of RE and MRE provided by this procedure. This is especially important when it refers to the rainiest and most erosive month of the year, knowing that are the month where occur the critical values of EI_{30}, which is very important for planning purposes and the application of conservation practices for soil and water resources. In this case, whenever it is possible, it is important to obtain the relationship between EI_{30m} and Rc_m for the location, even though it is for a small series of pluviograph data. Then use the pluviometric data series to estimate the EI_{30}. However, when the extrapolation process is necessary, it is essential to do a detailed study of the similarity of the pluviometric characteristics (minimum, mean and maximum of daily, monthly and annual precipitation) between locations, using statistic methods.

Table 5 shows the mean EI_{30} index and R factor values calculated from historic series of pluviometric data from cities of Cáceres-MT (1970 to 1985 and 1993 to 2009) and Rondonópolis-MT (1968 to 1988 and 1993 to 2009).

Table 5. Statistics parameters from monthly and annual distribution of the erosivity index EI_{30} obtained from historic series of pluviometric data of the cities of Cáceres (1970 to 1985 and 1993 to 2009) and Rondonópolis (1968 to 1988 and 1993 to 2009)

year	Erosivity index EI_{30} [MJ mm ha^{-1} h^{-1}]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
							Cáceres						
Me	893	796	753	405	255	101	77	31	209	542	673	843	5.579
Mx	1.805	1.328	1.763	1.248	760	447	284	188	572	1.208	1.428	1.425	6.882
Mn	316	369	0	133	0	0	0	0	0	0	224	278	4.561
SD	313.0	261.3	351.1	273.9	179.8	116.4	90.3	45.4	165.4	289.7	348.4	309.3	505.0
MSE	54.5	45.5	61.1	47.7	31.3	20.3	15.7	7.9	28.8	50.4	60.7	53.8	87.9
C.V.	35.1	32.8	46.6	67.5	70.5	115.5	117.1	144.2	78.9	53.5	51.8	36.7	9.1
							Rondonópolis						
Me	1.255	1.065	825	426	214	49	45	63	282	554	866	1.260	6.904
Mx	1.973	2.585	1.665	965	931	271	244	738	851	1.012	1.593	1.847	8.519
Mn	483	415	151	146	0	0	0	0	0	116	276	382	5.924
SD	394.7	447.0	290.4	218.7	208.6	76.4	64.4	130.9	202.1	205.1	327.7	300.3	538.6
MSE	68.7	77.8	50.5	38.1	36.3	13.3	11.2	22.8	35.2	35.7	57.0	52.3	93.8
C.V.	31.5	42.0	35.2	51.3	97.4	157.2	143.2	208.8	71.6	37.0	37.9	23.8	7.8

Me- mean; Mx - maximum; Mn - minimum; SD - standard deviation; MSE - mean standard error; C.V. - coefficient of variation

In general, the highest erosivity index EI_{30} amounts for both cities occur from october to march. December, january and february were the most erosive months, being responsible for 45% (in Cáceres) and 52% (in Rondonópolis) of the total annual erosivity. This seasonal and annual distribution is similar to the results obtained by Morais et al. (1991) for the Southeastern Mato Grosso. However, these authors observed that the rainiest months (december, january and february) are generally responsible for 50 and 66% of the precipitation and total annual erosivity, respectively. The disagreement of proportionality, despite the stations considered in both studies being in the same region, can be explained by the difference of periods of the data that were used to characterize the EI_{30} in both studies. This emphasizes the importance of using a long series of data (20 years minimum), making it possible to obtain a mean value more representative of the cyclical variability of rainfall erosive potential.

The pluviometric data shows that both cities have similar pluviometric variation throughout the year, in which the mean monthly erosivity index was higher in the period with higher precipitation, corresponding to the months from october to march, which present an EI_{30} value greater than 500 MJ mm ha^{-1} h^{-1} month^{-1} (critical value according to Rufino, 1986), contributing, on average, with 81% and 84% of the value of total annual erosivity for Cáceres and Rondonópolis, respectively (Table 5).

Analyzing quantitatively the rainfall precipitation and its monthly and annual erosivity, we observe that the city of Rondonópolis is rainier and with more erosive rainfalls than the city of Cáceres (Table 5). Furthermore, 15.6 and 19.3% of the total annual erosivity occurs in the period of lower precipitation (april to september) for Rondonópolis and Cáceres, respectively, which means that for the region of Rondonópolis the erosivity is more concentrated in the rainy period in comparison to Cáceres.

The R factor value from the station of Cáceres obtained in this study is 28% lower than that obtained by Morais et al. (1991) for the same station. This difference might be due the fact that, in the study of Morais et al. (1991), the values of EI_{30}m were obtained from the relationship between EI_{30}m and Rc_m adjusted for the station of Flechas, which can provide a great inaccuracy on estimates of EI_{30}, since there is big spatial variability of EI_{30} in this region (ALMEIDA, 2009).

The mean values of R factor for Cáceres and Rondonópolis are 5,579 and 6,904 MJ mm ha^{-1} h^{-1} year^{-1} and, with return period estimated of 2.1 and 3.7 years and probability of occurrence of 46.8 and 26.9%, respectively. This values fall within the range of variation from 3,116 to 20,035 MJ mm ha^{-1} h^{-1} year^{-1}, found by Silva (2004) through the map of rainfall erosivity for Brazil, and closer to the lower limit of range set for the country, which is from 5,000 to 12,000 MJ mm ha^{-1}h^{-1}year^{-1}, according to Cogo, Levien and Schwarz (2003), where it can be considered medium to high in accordance with the classification of Foster et.al. (1981).

The factor R average values obtained for the stations of Cáceres and Rondonópolis were similar those observed in others stations in Brazil (MELLO et al., 2007; OLIVEIRA et al., 2012; VIOLA et al., 2014; WALTRICK et al., 2015). However, these results were discrepant and higher than R values obtained in temperate regions, for example in the central region of Chile (BONILLA; VIDAL, 2011), in Switzerland (MEUSBURGUER et al., 2011), in Italy (BORRELLI; DIODATO; PANAGOS, 2016) and in Slovenia (MIKOŠ; JOŠT; PETKOVŠEK, 2006). In this regions the average R factor values were equals a 1337, 1330, 1800 and 2246 MJ mm ha^{-1} h^{-1} year^{-1}, respectively, all classified with low erosivity, according Foster et al. (1981). In China, where occur climates tropical and temperate, Qin et al. (2016) found R values ranging from 8000 to 15000 MJ mm ha^{-1} h^{-1} year^{-1} in the tropical climate regions and values ranging from 1500 to 6000 in regions where the temperate climate is relatively predominant. This highest values in the tropical regions are due to the predominance of convective rains, which have

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high values of intensity and high kinetic energy of raindrops (OLIVEIRA et al., 2012; MACHADO et al., 2014).

The distribution curves of probability of the erosivity values of annual and maximum monthly (Fig. 3) for both cities followed the Gumbel standard, simplified by VenTe Chow, typical of extreme events of precipitation (PINTO, 1996). In Table 6 the return period, probability of occurrence and the most critical values of erosivity indexes observed for the cities of Cáceres and Rondonópolis are found, considering the period from the series of pluviometric data.

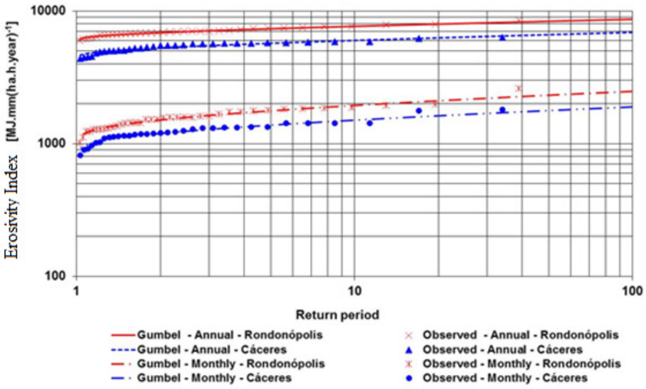

Fig. 3. Distribution curve of return period from monthly [MJ.mm(ha.h.month)$^{-1}$] and annual [MJ.mm(ha.h.year)$^{-1}$] rainfall erosivity based on historic series of pluviometric data of the cities of Rondonopolis (1968-1988 and 1993-2009) and Caceres (1970-1985 and 1993-2009).

Table 6. Probability of occurrence and return period from the values of annual erosivity indexes ($EI_{30annual}$.MJ mm ha^{-1} h^{-1} year^{-1}) and the month of the most erosive rainfall of the year based on historic series of pluviometric data of the cities of Rondonópolis (1968-1988 and 1993-2009) and Cáceres (1970-1985 and 1993-2009)

Cáceres							Rondonópolis						
Year	$EI_{30annual}$	m	TR	Pr	Month with larger rainfall		Year	$EI_{30annual}$	m	TR	Pr	Month with larger rainfall	
					Month	$EI_{30monthly}$						Monthly	$EI_{30monthly}$
1974	6.882	1	39.00	2.56	Apr	1.248	1976	8.519	1	39.00	2.56	Feb	2.585
1982	6.525	2	19.50	5.13	Mar	1.221	1978	7.887	2	19.50	5.13	Jan	1.930
1995	6.062	3	13.00	7.69	Feb	1.216	1968	7.793	3	13.00	7.69	Dec	1.820
1998	6.058	4	9.75	10.26	Dec	1.425	1979	7.600	4	9.75	10.26	Jan	1.834
1976	6.004	5	7.80	12.82	Feb	1.328	1998	7.575	5	7.80	12.82	Dec	1.596
1981	5.942	6	6.50	15.38	Jan	1.331	1987	7.465	6	6.50	15.38	Jan	1.564
2002	5.915	7	5.57	17.95	Feb	1.144	1995	7.370	7	5.57	17.95	Dec	1.345
2007	5.879	8	4.88	20.51	Jan	1.805	1999	7.357	8	4.88	20.51	Jan	1.973
1983	5.868	9	4.33	23.08	Nov	1.427	2005	7.283	9	4.33	23.08	Jan	1.862
1984	5.862	10	3.90	25.64	Nov	1.428	1984	7.197	10	3.90	25.64	Jan	1.562
2006	5.842	11	3.55	28.21	Feb	1.098	1975	7.131	11	3.55	28.21	Nov	1.593
1978	5.839	12	3.25	30.77	Dec	1.331	1977	7.066	12	3.25	30.77	Dec	1.548
1997	5.830	13	3.00	33.33	Jan	1.175	1974	6.972	13	3.00	33.33	Mar	1.665
1985	5.752	14	2.79	35.90	Jan	969	2006	6.971	14	2.79	35.90	Jan	1.518
1996	5.724	15	2.60	38.46	Mar	1.315	2008	6.953	15	2.60	38.46	Jan	1.329
2001	5.669	16	2.44	41.03	Dec	1.281	1997	6.951	16	2.44	41.03	Jan	1.291
2003	5.668	17	2.29	43.59	Mar	1.763	1900	6.886	17	2.29	43.59	Jan	1.275
1979	5.662	18	2.17	46.15	Dec	1.175	1970	6.882	18	2.17	46.15	Dec	1.258
1999	5.559	19	2.05	48.72	Mar	1.130	1981	6.842	19	2.05	48.72	Jan	1.423
2000	5.534	20	1.95	51.28	Jan	898	1996	6.802	20	1.95	51.28	Jan	1.413
1972	5.433	21	1.86	53.85	Nov	1.420	1983	6.801	21	1.86	53.85	Dec	1.575
1975	5.415	22	1.77	56.41	Jan	1.309	1988	6.771	22	1.77	56.41	Jan	1.767
2009	5.299	23	1.70	58.97	Feb	1.186	2002	6.770	23	1.70	58.97	Jan	1.425
1970	5.236	24	1.63	61.54	Oct	1.208	2009	6.740	24	1.63	61.54	Dec	1.509
1980	5.216	25	1.56	64.10	Mar	1.146	2000	6.731	25	1.56	64.10	Fev	1.720
1977	5.161	26	1.50	66.67	Jan	1.133	2007	6.682	26	1.50	66.67	Dec	1.382
1973	5.136	27	1.44	69.23	Nov	1.115	1994	6.681	27	1.44	69.23	Nov	1.230
2004	5.081	28	1.39	71.79	Nov	818	2003	6.622	28	1.39	71.79	Dec	1.228
2008	5.080	29	1.34	74.36	Dec	1.316	1986	6.591	29	1.34	74.36	Feb	1.724
2005	4.984	30	1.30	76.92	Mar	1.026	1980	6.544	30	1.30	76.92	Jan	1.425
1994	4.711	31	1.26	79.49	Dec	1.166	1993	6.530	31	1.26	79.49	Feb	1.801
1971	4.706	32	1.22	82.05	Feb	914	1982	6.511	32	1.22	82.05	Dec	1.105
1993	4.561	33	1.18	84.62	Nov	1.013	2004	6.330	33	1.18	84.62	Jan	1.761
Me	5.579						1971	6.240	34	1.15	87.18	Dec	1.300
Mx	6.882						1973	6.174	35	1.11	89.74	Nov	1.575

SD	505
MSE	88
C.V.	9

1969	6.101	36	1.08	92.31	Jan	1.275
1985	6.098	37	1.05	94.87	Jan	1.514
1972	5.924	38	1.03	97.44	Nov	1.011
Me	6.904					
Mx	8.519					
SD	539					
MSE	87					
C.V.	8					

$EI_{30annual}$ - Annual erosivity index in MJ mm ha^{-1} (year)$^{-1}$; m- Order number; TR - Return period; Pr - Probability of occurrence; $EI_{30monthly}$ - Monthly erosivity index in MJ mm ha^{-1} h^{-1}; Me - mean; SD - standard deviation; Mx - maximum; MSE - mean standard error; C.V. - coefficient of variation in %.

We can observe that, for Cáceres, the month that presented the higher value of EI_{30} (1,805 MJ mm ha^{-1} h^{-1}) was january 2007, whereas for Rondonópolis it was february 1976, with EI_{30} of 2,585 MJ mm ha^{-1} h^{-1}. These exceptional peaks in rainfall erosivity, are responsible for great damage to the crops by occurrence of water erosion process (MAZURANA et al., 2010). Applying the probability function described by Eqs. 10, 11 and 12, it verifies that these peaks have a return period of 59 and 175 years for Cáceres and Rondonópolis, respectively.

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CONCLUSIONS

1. In the Mato Grosso State, values of EI_{30} estimated from equations relating precipitations, rainfall coefficient and erosivity for our study areas, even if obtained from a small series of pluviograph data, are more reliable than the values estimated from equations developed for nearby locations, even than this locations are inside the limits of State.
2. The proximity between two locations should not be used as a unique condition to extrapolate the values of EI_{30m} and Rc_m since this information is not necessarily related with the similarity of the physical rainfall characteristics in different locations.
3. The relationship between EI_{30} and Rc expressed by equations 13 ($142.1953 \times Rc_m^{0,5261}$) and 14 ($171.6612 \times Rc_m^{0,5240}$) present great reliability to determine the erosive potential of rainfalls for the stations of Cáceres and Rondonópolis, respectively.
4. The stations of Cáceres and Rondonópolis have average R values equal to 5,579 and 6,904 MJ mm ha^{-1} h^{-1} year^{-1}, with return period estimated of 2.1 and 3.7 years and probability of occurrence of 46.8 and 26.9%, respectively.
5. For both stations, the most erosive months are december, january and february, which corresponds to 45% (Cáceres) and 52% (Rondonópolis) of the annual erosivity.
6. The factor R values of the Cáceres and Rondonopolis stations were similar to obtained in other Brazilian regions, however was higher those found in temperate regions.

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