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Apoio: PRPPG/PROAPUPEC
| Jataí-GO | n.14 | jan-jun/2010 |
ISSN 1679-9860

THE INFLUENCE OF THE BRAZILIAN *CERRADO* DEFORESTATION IN GRAIN CULTURE AND ITS CONSEQUENCES TO LOSSES THE SOIL IN THE CACHOEIRA DOURADA RESERVOIR REGION – CENTRAL - WESTERN BRAZIL

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Abstract

The erosivity index (EI30) and its spatialization were determined for the contribution basins of the Cachoeira Dourada hydroelectric system reservoir, located between the states of Goiás and Minas Gerais and limited by coordinates 640000-760000 m W and 7910000-7975000 m N. Average monthly and annual rainfall data corresponding to eight localities and to a 30-year period were treated. It was observed that in this period the average annual rainfall was 1441 mm, the highest and lowest indexes having occurred respectively in January and July (7.5 mm). EI30 varied from 7100 to 8500 MJ mm $(ha\ h)^{-1}$. The most representative period was October to March, corresponding to 7880.3 MJ mm $(ha\ h)^{-1}$and 94% of the average annual EI30. The average rainfall variation coefficient for all stations was 82.73%. There is an irregular rainfall distribution in the region and consequently a non-uniform spatialization of the erosivity indexes within the influence area of the reservoir. The highest rainfall values coincide with the period of soil preparation and development of annual-cycle plants, mainly soybean and corn.

Key words: Deforestation, (EI30) rain erosivity factor, soil loss.

Resumen

LA INFLUENCIA DE LA DEFORESTACIÓN DEL CERRADO BRASILEÑO EN EL CULTIVO DE GRANOS Y LAS CONSECUENCIAS DE LA PÉRDIDA DEL SUELO

Artigo recebido para publicação em 16 de Maio de 2009;
Artigo aprovado para publicação em 28 de Fevereiro de 2010

EN LA REGIÓN DE LA RESERVA CACHOEIRA DOURADA - BRASIL CENTRAL – OCCIDENTAL

El índice de erosividad (EI30) y su espacialización fueron determinados para las cuencas de contribución del sistema hidroeléctrico de la reserva Cachoeira Dourada, localizada entre los estados de Goias y Minas Gerais, limitada por las coordenadas 640000-760000 m W. y 7910000-7975000 m S. UTM zona 22, Datum Córrego Alegre, Se trataron los datos del promedio mensual y anual de las precipitaciones correspondientes a ocho localidades para un periodo de treinta años. Se observó que para ese periodo el promedio anual de precipitación fue de 1441 mm, presentándose el índice más alto y el más bajo en enero y julio (7.5mm) respectivamente. El EI30 varió de 7100 a 8500 MJmm (ha h)$^{-1}$. El periodo más representativo fue de octubre a marzo con 7880.3 MJmm (ha h)$^{-1}$ que corresponde al 94% del promedio anual del EI30. El coeficiente de la variación del promedio anual de precipitacion fue de 82.73% para todas las estaciones. Existe una distribución irregular de precipitación en la región y en consecuencia una espacialización no uniforme de los índices de erosión en el área de influencia de la reserva. Los valores más altos de precipitación coinciden con el periodo de preparación de la tierra para el cultivo y el desarrollo de las plantas de ciclo anual, principalmente soya y maíz.

Palabras clave: Deforestación, (EI30) factor de erosión por lluvia, perdida del suelo.

Resumo

A INFLUÊNCIA DO DESMATAMENTO DO CERRADO BRASILEIRO PARA CULTIVO DE GRÃOS E SUAS CONSEQUÊNCIAS NAS PERDAS DE SOLO NA REGIÃO DO RESERVATÓRIO DE CACHOEIRA DOURADA – CENTRO OESTE DO BRASIL

Determinou-se o índice de erosividade (EI30) e a espacialização do mesmo nas bacias de contribuição do reservatório da hidroelétrica Cachoeira Dourada localizada entre os Estados de Goiás e Minas Gerais, limitado pelas coordenadas 640000 a 760000m E e 7910000m a 7975000m N. Utilizou-se dados de 8 localidades referente a 30 anos das precipitações médias mensais e anuais. Verificou-se que neste período a precipitação média anual foi de 1.441 mm, sendo que o maior índice ocorreu no mês de janeiro e o menor em julho com 7,5 mm. O EI30 variou de 7.100 a 8.500 MJ mm (ha h)$^{-1}$, cujo período mais representativo concentrou-se nos

meses de outubro a março com 7.880,3 MJ mm (ha h)$^{-1}$, correspondendo a 94% do EI30 médio anual. O coeficiente de variação médio das precipitações para todas as estações foi de 82,73%. Existe uma distribuição irregular das chuvas na região e como conseqüência uma espacialização desuniforme dos índices de erosividade dentro da área de influência do reservatório. As maiores precipitações coincidem com o período de preparo dos solos e desenvolvimento das plantas de ciclo anual principalmente a soja e o milho.
Palavras-Chave: Desmatamento, Chuva, fator EI30, perdas de solo.

1 - Introduction

The *Cerrado*, a type of savanna in Brazil, is a biome that occupies 24% of the Brazilian territory and is a major biodiversity in South America, second only to Amazonia. It has been intensively deforested since the 80’s, giving place to mainly soybean and corn cultures. This practice leads to series of negative consequences such as the reduction of biodiversity and soil loss due to erosion processes. Rainfall is concentrated in the months from October to March, with a monthly rainfall exceeding 300 mm.

Erosion is the main reason why soils lose their productivity capacity. The removal of native vegetation leads to a break, either temporary or definitive, of the natural equilibrium that exists between soil and environment. In general the preparation of soil for agriculture starts with the removal of the native vegetation and therefore the soil exposition to erosion by rainwater (hydric erosion).

On the basis of physical characteristics of the rainfall in each region, the rainwater potential to cause hydric erosion can be evaluated by means of erosivity indexes. Wischmeier & Smith (1958) determined that the product of the total kinetic energy by the maximum intensity in 30 minutes (EI30) is the parameter that best expresses the rainwater potential to cause erosion in terms of raindrop impact phases, soil disaggregation, flow turbulence and transport of particles.

The rainwater erosivity is a factor that represents the capacity of rainwater to cause erosion of the soil. In essence the rainwater erosivity depends on the intensity with which the rain falls and the kinetic energy of the impact of the raindrops on the soil surface. According to Wischmeier (1959), the total rainfall kinetic energy and its maximum intensity in 30 minutes in MJ mm^{-1} h^{-1} are the parameters that best correlate with soil loss by hydric erosion.

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The sum of the average monthly EI30 values for a certain period of years of rainfall is the factor R of the soil loss equation, given in MJ mm^{-1} h^{-1}. The erosivity index is thus determined for the rain that falls in a certain hydrographic basin.

R is a numeric index that expresses the rain capacity to erosion in a non-protected area (Bertoni & Lombardi Neto, 1999; Alves, 2000). Wischmeier & Smith (1978) demonstrated that the index that best correlates with soil loss in the USA is the product of the rain kinetic energy and the maximum rain intensity in 30 minutes. Bertoni & Lombardi Neto (1999) proposed the following equation to determine the average erosivity index value by means of the relation between the average monthly and annual rainfall:

$$\mathbf{EI30 = 67.355\ (r^2 / P)^{0.85}} \quad \textbf{Equation 1}$$

where:

EI30 = average monthly erosivity index in MJ mm ha^{-1} h^{-1};

r = average of the total monthly rainfall (mm);

P = average of the total annual rainfall (mm).

An estimate of the average annual soil loss is obtained using the Universal Soil Loss Equation. Rainwater is the active agent of the hydric erosion process because it causes disaggregation of soil particles.

Alves (2000), Bertoni & Lombardi Neto (1999), Albuquerque et al., (1994) among others studied other erosivity indexes and considered EI30 as the most suitable for the intertropical scenario. According to Lal (1976) and Streei et al., (2002), the Wischmeier & Smith’s (1958) model underestimates the raindrop kinetic energy in tropical regions, because of wind velocity, distribution of drops of different sizes and high rainfall indexes. A better correlation between soil loss and EI30 erosivity index, according to Wischmeier (1958) is not possible because the rain physical characteristics are not known.

Detail studies of these parameters are rare in Brazil. In order to contribute to such information, Wagner & Massambani (1988) determined the relation between kinetic energy and rainfall rate, obtained from 533 samples of the distribution of raindrops in predominantly convective (small volume, short duration and high intensity) rainfall in the São Paulo region. The authors concluded that the equation to calculate the kinetic energy obtained according to the data observed does not significantly differ from that proposed by Wischmeier & Smith (1978). According to Eltz et al., (1992) rainfall events with the same erosivity capacity can

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cause different soil losses, depending on the moisture previous to rainfall and the variation of their intensity.

Our objective was to determine EI30 values and their spatial distribution using data corresponding to a 30-year period (1973 to 2002) from eight rainfall stations in different localities of the drainage area of the Cachoeira Dourada reservoir.

2 – Materials and Methods

2.1 - Characterization of study area

The Cachoeira Dourada hydroelectric system reservoir (GO/MG) is located on the limit of the states of Goiás and Minas Gerais, in the *Cerrado* biome within the coordinates 640000-760000 m W and 7910000-7975000 m N. It was built in 1959 to generate electric energy and as part of the complex of dams situated along the Paranaíba river whose drainage basin occupies an area of 2734 km^2.

2.2 - Methods

Data referrig to eight localities (Table 1) and to a 30-year period, from 1973 to 2002, were obtained from the National Agency for Waters (*Agência Nacional de Águas* - ANA). The regional weighting method (Bertoni & Tucci, 2000) was used to replace missing data in the monthly series, once at least three stations should have a minimum amount of data corresponding to ten years. The missing data Y corresponding to the 1993-2002 decade was calculated for the Tupaciguara station using the following equation, where the average was taken from three values calculated from rainfalls at points X1, X2 and X3 during the month in question:

$$Yc=1/3(X1/Xm1+X2/Xm2+X3/Xm3)Ym \quad \text{Equation 2}$$

where:

Yc = estimated rainfall at station Y;

X1, X2 and X3 = rainfalls corresponding to the month (or year) for which data are missing and measured in three neighboring stations;

Ym = average rainfall at station Y;

Xm1, Xm2 and Xm3= average rainfalls at the three neighboring stations.

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Table 1- Distribution of the rainfall stations.

Locality	Latitude (UTM)	Longitude (UTM)	Altitude (m)	Period (years)
Fazenda Cachoeira Pouso Alegre	733914	7931098	793	1973-2002
Xapetuba	754563	7912650	890	1973-2002
Tupaciguara	743696	7941832	887	1973-2002
Avantiguara	703467	7923302	791	1973-2002
Monte Alegre de minas	724452	7911960	730	1973-2002
Ponte Meia	646788	7971760	468	1973-2002
Brilhante	721433	7954069	800	1973-2002
Corumbazul	726453	7981721	500	1973-2002

In this method, the relation between the rainfalls measured in each station and the respective averages helps to predict the rainfall at the station where data are missing. It is assumed that at a station Y the missing data are proportional to the rainfall measured at the neighboring stations X1, X2 and X3 during the same period. It must be taken into account, however, that the chosen neighboring stations must be located in a region with a climate similar to that of the station where data are missing. The erosivity indexes (EI30) are calculated according to Equation 1.

By means of the software *Surfer r.8.0* – grid module, the kriging method was applied to the georeferenced data banks to generate erosivity contour maps (according to Landim 2000, Landim et al., 2002).

3 - Results and Discussion

3.1 - Analysis of the data for the 30-year period: 1973-2002

The data in Table 2 correspond to eight rainfall stations and the 30-year period from 1973 to 2002. The average annual rainfall was 1441 mm; the highest and lowest average monthly index occurred respectively in January (273.3 mm) and July (7.5 mm).

There is an irregular distribution of rainfall, with concentration of values higher than 100 mm between October and March, when the rainy summer predominated and 85.27% of the total rainfall took place. On the other hand, between April and September, 14.73% of the total rainfall took place, corresponding to a prolonged dry period, which characterizes the Brazilian Central-Western region.

Table 2 - Descriptive statistics of the average monthly rainfall (mm) from 1973 to 2002 for the 12 microbasins of the Cachoeira Dourada hydroelectric system reservoir

Stations	Average	**SD**	**VC**	**P**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Ago**	**Sept**	**Oct**	**Nov**	**Dec**
Fazenda Cachoeira Pouso Alegre	109.11	87.41	80.11	1309	240.0	174.2	178.5	73.0	42.3	15.8	6.9	17.1	47.9	100.4	178.0	235.2
Xapetuba	121.69	97.47	80.10	1460	254.7	205.9	198.2	90.6	53.1	20.4	8.6	19.1	43.0	101.7	190.8	274.2
Tupaciguara	119.26	100.25	84.06	1431	261.0	185.9	183.5	70.1	37.3	17.2	8.3	17.4	46.0	112.7	212.8	278.9
Avantiguara	126.46	105.95	83.78	1518	320.8	198.1	185.3	89.7	38.6	17.6	6.4	18.7	51.5	128.4	195.1	267.3
Monte Alegre de minas	126.11	102.23	81.06	1513	290.2	195.1	192.6	89.4	41.0	17.7	10.4	17.7	52.7	126.7	207.7	272.1
Ponte Meia	120.30	95.97	79.78	1444	256.7	188.6	201.5	101.0	38.0	14.5	5.5	17.3	51.4	117.1	192.7	259.3
Brilhante	128.64	115.84	90.05	1544	330.2	201.2	189.4	67.0	36.3	15.1	7.2	16.3	59.6	106.4	198.5	316.5
Corumbazul	109.22	90.56	82.92	1311	232.6	163.5	188.6	74.8	34.7	12.4	7.0	16.3	39.9	103.5	189.0	248.3
Monthly average				1441	**273.3**	**189.1**	**189.7**	**82.0**	**40.2**	**16.3**	**7.5**	**17.5**	**49.0**	**112.1**	**195.6**	**269.0**

VC = Variation coefficient (%); **SD** = Standard deviation; **P** = Average annual rainfall (mm)

For all localities high variation coefficients were obtained, the highest and the lowest values corresponding respectively to the Brilhante (90%) and Ponte Meia stations (79.78%). These high indexes are explained by the broad rainfall range, from 5.5 mm to 330 mm.

The arithmetic average is influenced by such extreme values, as Silva et al., (2003) also observed. According to Figure 1, a variation of the index EI30 occurred, from 7100 MJ mm ha^{-1} h^{-1} at the headwater of the major Córrego Piedade affluent (Fazenda Cachoeira Pouso Alegre station) to 8500 MJ mm ha^{-1} h^{-1} in the Córrego Alambari region (Brilhante station). The maximum EI30 index is close to the value of 8.319 MJ mm ha^{-1} h^{-1} obtained by Dedecek (1978) for the Planalto Central C*errado* (Brasília – DF).

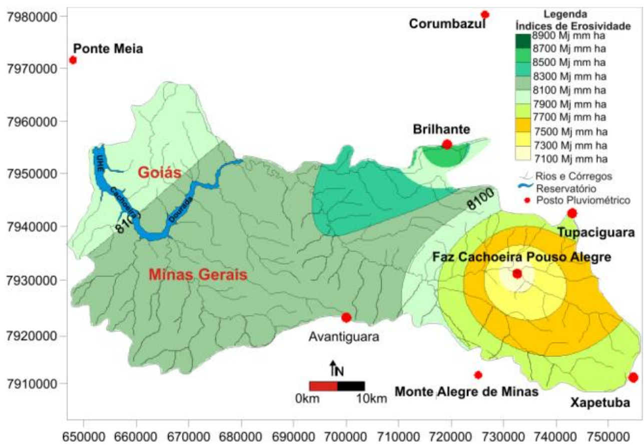

Figure 1 - Erosivity spatialization (EI30) in the influence area of the Cachoeira Dourada hydroelectric system reservoir from 1973 to 2002.

On the other hand, it is much lower than 11635 MJ mm ha^{-1} h^{-1} obtained by Rufino et al., (1993) for the Cascavel city. The 30-year average annual erosivity factor EI30 was 7410.4

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MJ mm ha^{-1} h^{-1} (Table 3), corresponding to 94% of the total EI30 and falling in the 5000-12000 MJ mm ha^{-1} h^{-1} interval for Brazilian conditions (Cogo, 1988). Part of the period with the highest EI30 indexes coincides with soil preparation and seeding for annual crops. Aiming at decreasing soil losses, conservationist practices should be preferred, being direct seeding one of the most recommended measures.

Table 3 - Average monthly erosivity index from 1973 to 2002 for the 12 microbasins of the Cachoeira Dourada hydroelectric system reservoir

Stations	**EI1**	**EI2**	**EI3**	**EI4**	**EI5**	**EI6**	**EI7**	**EI8**	**EI9**	**EI10**	**EI11**	**EI12**	**R**	**EI30 wet**	EI30 dry
Faz Cachoeira Pouso Alegre	1679.8	974.2	1015.5	222.1	87.8	16.5	4.0	18.8	108.5	381.8	1010.6	1623.0	7142.73	6685.0	457.8
Xapetuba	1693.7	1179.8	1105.8	292.2	117.8	23.2	5.3	20.7	82.3	355.7	1036.5	1920.0	7833.13	7291.5	541.6
Tupaciguara	1796.1	1008.8	986.8	192.2	65.8	17.6	5.1	18.0	93.9	430.8	1269.4	2010.5	7895.20	7502.6	392.6
Avantiguara	2426.7	1069.3	954.5	278.1	66.3	17.4	3.1	19.3	108.3	511.6	1042.0	1779.5	8276.26	7783.7	492.6
Monte Alegre de minas	2051.3	1044.4	1021.8	277.1	73.6	17.7	7.2	17.7	112.9	501.4	1161.7	1838.5	8125.09	7619.0	506.1
Ponte Meia	1733.3	1026.3	1148.4	355.0	67.4	13.1	2.5	17.7	112.6	456.4	1064.5	1763.2	7760.32	7192.1	568.2
Brilhante	2512.0	1082.1	976.4	166.9	58.9	13.3	3.8	15.1	136.8	366.3	1057.5	2337.4	8726.33	8331.7	394.6
Corumbazul	1591.3	874.0	1114.1	231.3	62.7	10.9	4.1	17.3	79.5	401.7	1118.2	1778.2	7283.31	6877.5	405.8
Average	**1935.5**	**1032.4**	**1040.4**	**251.9**	**75.0**	**16.2**	**4.4**	**18.1**	**104.3**	**425.7**	**1095.0**	**1881.3**	**7880.3**	**7410.4**	**469.9**

3.2 - Analysis of the data for the first 10-year period: 1973-1982

The data in Table 4 refer to the first decade of the 30-year series. The average annual rainfall was 1538 mm, the major part corresponding to the Brilhante station with 1693 mm, where the highest variation coefficient of 88.91% was observed.

The lowest rainfall values of 1402 mm occurred in the Fazenda Cachoeira Pouso Alegre region. The highest and lowest average monthly indexes correspond respectively to December (296.2 mm) and July (7.6 mm). Values higher than 100 mm were concentrated between October and March. Figure 2 shows that EI30 varied from 7600 MJ mm ha^{-1} h^{-1} at the Córrego Piedade headwater, next to the Fazenda Cachoeira Pouso Alegre station, and 9200 MJ mm ha^{-1} h^{-1} in the Córrego Alambari region, next to the Brilhante station.

Table 4 - Descriptive statistics of the average monthly rainfall (mm) from 1973 to 1982 for the 12 microbasins of the Cachoeira Dourada hydroelectric system reservoir

Stations	Average	**SD**	**VC**	**P**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Ago**	**Sept**	**Oct**	**Nov**	**Dec**
Fazenda Cacheira Pouso Alegre	116.8	96.05	82.23	1402	259.2	154.6	189.7	76.4	45.5	21.3	5.0	14.1	46.0	112.7	217.4	259.7
Xapetuba	130.55	99.56	76.26	1567	259.1	240.1	195.3	135.4	78.9	29.5	11.1	14.4	33.5	101.7	188.6	279.0
Tupaciguara	124.54	106.47	85.49	1495	281.6	172.0	156.2	80.0	37.8	20.2	9.9	9.8	44.2	142.6	248.6	291.9
Avantiguara	136.36	118.12	86.62	1636	352.3	195.6	161.1	86.5	49.9	19.5	7.0	11.2	47.8	164.2	238.6	302.6
Monte Alegre de Minas	132.27	104.95	79.34	1587	302.7	176.8	186.6	114.7	50.9	27.0	10.4	13.5	43.9	156.1	213.4	291.2

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Ponte Meia	125.98	109.00	86.52	1512	305.3	168.1	180.0	88.2	32.8	17.6	4.3	11.0	49.1	149.4	201.6	304.3
Brilhante	141.11	125.46	88.91	1693	363.4	188.0	176.9	79.0	45.2	21.4	9.6	15.4	63.9	132.9	254.0	343.6
Corumbazul	117.56	100.03	85.09	1411	230.7	160.8	171.2	78.1	35.0	15.1	3.3	16.4	41.5	134.0	227.7	296.9
Monthly average 1537,8					**294.3**	**182.0**	**177.1**	**92.3**	**47.0**	**21.5**	**7.6**	**13.2**	**46.2**	**136.7**	**223.7**	**296.2**

VC = Variation coefficient (%); SD = Standard deviation; **P** = Average annual rainfall (mm)

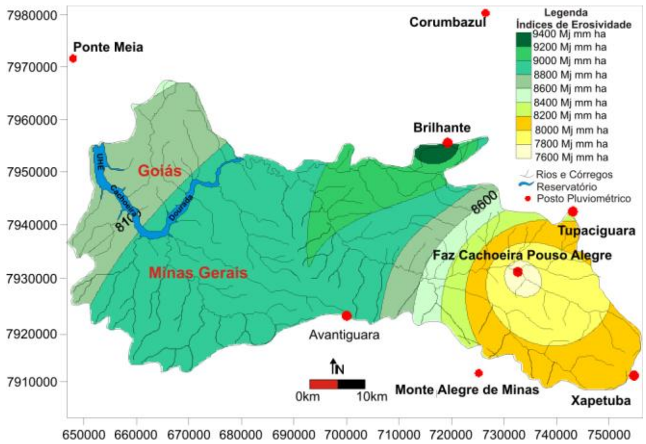

Figure 2 - Erosivity spatialization (EI30) in the influence area of the Cachoeira Dourada hydroelectric system reservoir from 1973 to 1982.

The average annual EI30, the sum of which between October and March reaching 7858.9 MJ mm ha^{-1} h^{-1}, corresponds to 93.8% of the total EI30. From April to September, EI30 resulted in 521.2 MJ mm ha^{-1} h^{-1}, representing only 6.21% of the erosivity index (Table 5). The correlation of this EI30 with that for the 30-year period results in a erosivity index of 521.2 MJ mm ha^{-1} h^{-1}, which corresponds to the months from April to September of the 1973-1982 period; it is higher than the erosivity index of 469.9 MJ mm ha^{-1} h^{-1} obtained for the same months of the 1973-2002 period. The same is observed during the months from October to March of 1973-1982 and 1973-2002 periods, which results from the higher rainfall index for 1973-1982 than for 1973-2002. Possibly soil loss was not conspicuous, once the occupation of *Cerrado* intensified in the following decade (1983-1992).

Table 5 - Average monthly erosivity index from 1973 to 1982 for the 12 microbasins of the Cachoeira Dourada hydroelectric system reservoir

Stations	EI1	EI2	EI3	EI4	EI5	EI6	EI7	EI8	EI9	EI10	EI11	EI12	R	EI30 wet	EI30 dry
Faz Cachoeira Pouso Alegre	1806.8	750.6	1062.8	226.5	93.8	25.8	2.2	12.8	95.6	438.5	1339.9	1812.8	7668.17	7211.5	456.7
Xapetuba	1642.7	1443.2	1015.9	545.0	217.6	40.9	7.8	12.1	50.7	335.0	957.4	1862.9	8131.08	7257.0	874.1
Tupaciguara	1969.5	851.9	723.2	231.9	64.8	22.3	6.6	6.5	84.6	619.4	1593.4	2093.5	8267.57	7850.8	416.8
Avantiguara	2668.9	981.6	705.7	245.2	96.2	19.5	3.4	7.6	89.5	729.0	1376.0	2060.9	8983.56	8522.2	461.4
Monte Alegre de minas	2116.2	848.3	929.8	406.5	102.2	34.8	6.9	10.7	79.4	686.5	1168.1	1981.3	8370.59	7730.1	640.5

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Ponte Meia	2238.0	811.5	911.6	271.1	50.4	17.5	1.6	7.9	100.2	664.1	1105.2	2225.6	8404.60	7955.9	448.7
Brilhante	2732.8	891.3	803.7	204.1	79.0	22.2	5.7	12.7	142.3	494.2	1486.5	2484.5	9358.91	8892.9	466.0
Corumbazul	1474.1	798.1	887.8	233.8	59.7	14.3	1.1	16.5	79.8	585.4	1441.7	2263.5	7855.75	7450.5	405.2
Average	**2081.1**	**922.0**	**880.1**	**295.5**	**95.5**	**24.7**	**4.4**	**10.8**	**90.3**	**569.0**	**1308.5**	**2098.1**	**8380.0**	**7858.9**	**521.2**

3.3 - Analysis of the data for the second 10-year period: 1983-1992

During this period an intense occupation of the C*errado* took place, the cause of deforestation being soil preparation for the development of rice, soybean and corn cultures. The average annual rainfall was 1490 mm (Table 6); the highest average monthly index of 272.4 mm occurred in December, which is higher than the 30-year index of 269 mm.

Table 6 - Descriptive statistics of the average monthly rainfall (mm) from 1983 to 1992 for the 12 microbasins of the Cachoeira Dourada hydroelectric system reservoir

Stations	Average	**SD**	**VC**	**P**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Ago**	**Sept**	**Oct**	**Nov**	**Dec**
Fazenda Cachoeira Pouso Alegre	112.49	88.57	78.47	1350	234.8	198.6	188.9	90.2	32.3	6.4	22.7	19.7	41.3	116.0	160.7	238.3
Xapetuba	128.03	100.61	78.58	1536	259.9	179.5	230.3	91.2	39.3	7.2	49.7	25.1	43.8	114.9	200.9	294.5
Tupaciguara	126.85	101.62	80.11	1522	256.1	187.3	225.4	85.1	32.9	6.8	52.4	24.5	42.1	107.0	206.8	295.8
Avantiguara	132.08	104.89	79.41	1585	328.8	194.0	216.4	121.4	22.7	7.6	51.0	23.5	51.0	140.6	162.0	265.9
Monte Alegre de minas	126.07	95.82	76.00	1513	270.8	203.2	192.2	99.3	32.3	5.6	46.8	23.9	50.9	124.4	209.1	254.3
Ponte Meia	125.53	94.15	75.00	1506	244.8	197.1	232.9	127.1	31.5	3.9	52.1	24.4	39.9	115.5	182.3	254.8
Brilhante	130.58	116.94	89.55	1567	349.1	216.4	191.4	70.9	25.8	3.0	47.4	20.7	50.2	115.6	161.0	315.5
Corumbazul	111.85	92.75	82.92	1342	218.3	175.0	211.9	82.9	26.8	3.2	20.6	26.8	37.6	90.3	188.7	260.1
1490,1	Monthly average				**270.3**	**193.9**	**211.2**	**96.0**	**30.5**	**5.4**	**42.8**	**23.6**	**44.6**	**115.5**	**183.9**	**272.4**

VC = Variation coefficient (%); **SD** = Standard deviation; **P** = Average annual rainfall (mm)

The spatial analysis (Figure 3) shows that the lowest erosivity index of 7200 MJ mm ha^{-1} h^{-1} corresponded to the areas close to the Fazenda Cachoeira Alegre rainfall station, whereas the highest erosivity index of 8600 MJ mm ha^{-1} h^{-1} corresponded to the Brilhante station neighboring areas. During this decade, the highest and the lowest average monthly indexes occurred respectively in December (272.4 mm) and June (5.4 mm).

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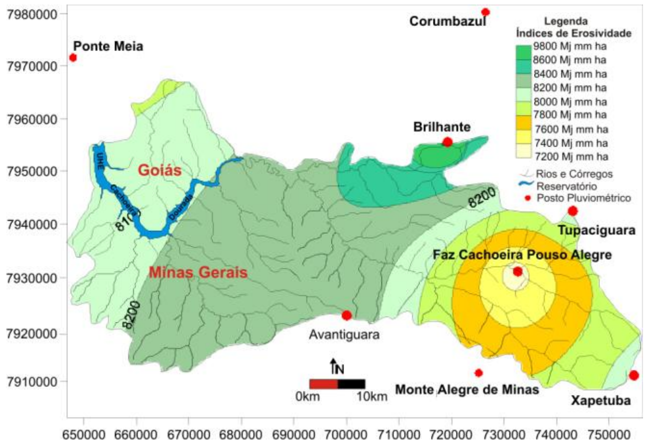

Figure 3 - Erosivity spatialization (EI30) in the influence area of the Cachoeira Dourada hydroelectric system reservoir from 1983 to 1992.

The least concentration of values lower than 100 mm occurred between May and September; the highest and the lowest variation coefficients correspond respectively to Brilhante (89.55%) and Ponte Meia (75%). The comparison of the data for the 1973-1982 and 1983-1992 periods shows a decrease in rainfall of 48 mm and consequent decrease of the average annual erosivity index in 600 MJ mm ha^{-1} h^{-1}. The average annual EI30 for this period was 7394.3 MJ mm ha^{-1} h^{-1} (Table 7), higher than those obtained by Margolis et al., (1995) for Caruaru – PE (2100 MJ mm ha^{-1} h^{-1}) and Rufino (1986) for some locations in Paraná (5.275 MJ mm ha^{-1} h^{-1}).

Table 7 - Average monthly erosivity index from 1983 to 1992 for the 12 microbasins of the Cachoeira Dourada hydroelectric system reservoir

Stations	**EI1**	**EI2**	**EI3**	**EI4**	**EI5**	**EI6**	**EI7**	**EI8**	**EI9**	**EI10**	**EI11**	**EI12**	**R**	**EI30 wet**	***EI30* dry**
Faz. Cachoeira Pouso Alegre	1577.1	1186.4	1089.9	309.9	54.1	3.4	29.7	23.4	82.0	475.2	827.6	1617.0	7275.65	6773.2	502.5
Xapetuba	1678.8	894.7	1367.3	283.1	67.8	3.7	100.9	31.5	81.3	419.2	1083.6	2076.1	8087.97	7519.6	568.3
Tupaciguara	1650.7	969.5	1328.2	253.5	50.4	3.5	111.2	30.5	76.6	374.5	1147.2	2108.6	8104.31	7578.6	525.7
Avantiguara	2439.4	994.2	1197.8	448.2	26.0	4.0	102.6	27.4	102.5	575.1	732.3	1699.4	8348.88	7638.2	710.7
Monte Alegre de minas	1824.3	1119.0	1018.8	331.5	49.2	2.5	92.3	29.5	106.3	486.4	1175.0	1638.8	7873.55	7262.3	611.2
Ponte Meia	1541.8	1066.8	1416.4	506.3	47.3	1.3	111.1	30.7	70.5	429.9	934.2	1650.9	7807.27	7040.0	767.3
Brilhante	2726.8	1209.2	981.6	181.3	32.5	0.8	91.5	22.3	100.9	416.3	731.1	2295.4	8789.75	8360.5	429.3
Corumbazul	1399.6	961.0	1330.6	269.9	39.5	1.1	25.3	39.7	70.4	312.1	1093.4	1885.3	7427.87	6982.0	445.8
Average	**1854.8**	**1050.1**	**1216.3**	**323.0**	**45.8**	**2.5**	**83.1**	**29.4**	**86.3**	**436.2**	**965.5**	**1871.4**	**7964.4**	**7394.3**	**570.1**

3.4 - Analysis of the data for the last 10-year period: 1993-2002

Table 8 shows that rainfall values higher than 100 mm were once more concentrated in the months between October and March. A decrease in the rainfall index is observed in the reservoir drainage area. The average annual rainfall in the last 10-year period was 1328 mm; the highest and the lowest average monthly values occurred respectively in January (255 mm) and July (5 mm).

Table 8 - Descriptive statistics of the average monthly rainfall (mm) from 1993 to 2002 for the 12 microbasins of the Cachoeira Dourada hydroelectric system reservoir

Stations	Average	**SD**	**VC**	**P**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Ago**	**Sept**	**Oct**	**Nov**	**Dec**
Fazenda Cachoeira Pouso Alegre	99.10	78.84	79.59	1189	225.9	169.4	157.0	52.5	49.1	19.7	5.1	17.6	56.4	72.7	156.1	207.6
Xapetuba	109.78	92.45	84.21	1317	245.2	198.2	168.9	45.3	41.1	24.6	4.0	17.9	51.7	88.3	183.0	249.1
Tupaciguara	109.78	92.45	84.21	1317	245.2	198.2	168.9	45.3	41.1	24.6	4.0	17.9	51.7	88.3	183.0	249.1
Avantiguara	114.68	95.53	83.30	1376	281.8	204.7	178.5	61.2	43.1	25.8	5.1	21.3	55.8	80.6	184.8	233.5
Monte Alegre de minas	122.72	105.30	85.81	1473	297.0	205.3	199.0	54.2	39.8	20.4	6.8	15.8	63.3	99.6	200.6	270.8
Ponte Meia	113.02	85.94	76.04	1356	220.0	200.5	191.5	87.7	49.5	21.9	3.7	16.5	65.3	86.4	194.4	218.8
Brilhante	117.50	105.39	89.69	1410	278.1	199.1	200.1	51.2	38.1	21.1	3.0	13.0	64.7	70.6	180.5	290.5
Corumbazul	99.13	82.47	83.19	1190	249.0	154.9	182.9	63.2	42.5	18.8	7.6	5.6	40.4	86.1	150.6	187.9
Monthly average				1328.5	**255**	**191**	**181**	**58**	**43**	**22**	**5**	**16**	**56**	**84**	**179**	**238**

VC = Variation coefficient (%); **SD** = Standard deviation; **P** = Average annual rainfall (mm)

Figure 4 shows that EI30 values varied from 6500 MJ mm ha^{-1} h^{-1} in the region of the headwater of the Córrego Piedade major affluent, close to the Fazenda Cachoeira Pouso Alegre station, to 7900 MJ mm ha^{-1} h^{-1} in the córrego Alambari region, close to the Brilhante station.

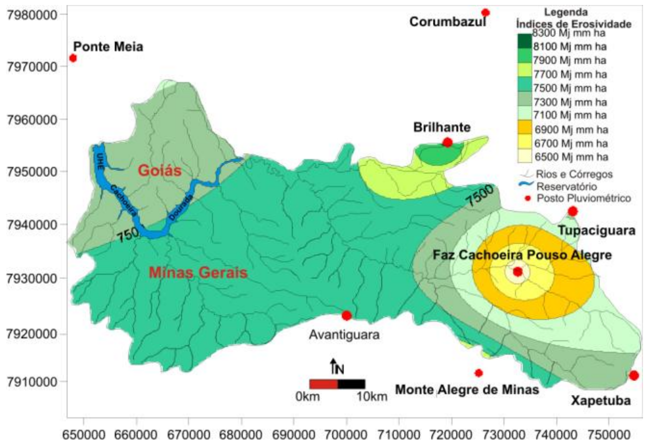

Figure 4 - Erosivity spatialization (EI30) in the influence area of the Cachoeira Dourada hydroelectric system reservoir from 1993 to 2002.

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On the basis of the average annual EI30 indexes for the last 10-year period, the average sum of EI30 values for the rainy months (October to March) reached 6940.3 MJ mm ha^{-1} h^{-1}, which corresponds to 94.15% of the annual EI30 index and is higher than the values obtained by Bertol (1993; 2002), of 6329.3 and 5790 MJ mm ha^{-1} h^{-1} respectively for Campos Novos and Lages (SC). This sum is lower than the values obtained by Morais et al., (1991), of 7830 and 8.493 MJ mm ha^{-1} h^{-1} for two distinct points of the Cáceres municipality (MT), and Silva et al., (1997), of 8355 MJ mm ha^{-1} h^{-1} for Goiânia (GO).

In the dry, April-September period, the average sum of EI30 values was 431.3 MJ mm ha^{-1} h^{-1}, which corresponds to 5.4% of the erosivity index; the highest and lowest average monthly indexes (Table 9) occurred respectively in January (1848.4 MJ mm ha^{-1} h^{-1}) and July (2 MJ mm ha^{-1} h^{-1}). The largest dada variation was observed at the Brilhante station (89.69%), whereas the lowest at the Ponte Meia station (76%).

Table 9 - Average monthly erosivity index from 1993 to 2002 for the 12 microbasins of the Cachoeira Dourada hydroelectric system reservoir.

Point	**EI1**	**EI2**	**EI3**	**EI4**	**EI5**	**EI6**	**EI7**	**EI8**	EI9	**EI10**	**EI11**	EI12	**R**	**EI30 wet**	**EI30 dry**
Faz Cachoeira Pouso Alegre	1644.9	1008.1	886.2	137.6	122.9	26.0	2.6	21.5	155.6	239.2	877.0	1424.8	6546.37	6080.1	466.3
Xapetuba	1733.1	1207.2	919.2	98.1	83.1	34.8	1.6	20.2	122.9	305.6	1054.0	1780.7	7360.48	6999.7	360.8
Tupaciguara	1733.1	1207.2	919.2	98.1	83.1	34.8	1.6	20.2	122.9	305.6	1054.0	1780.7	7360.48	6999.7	360.8
Avantiguara	2116.0	1228.4	973.0	157.9	86.9	36.4	2.3	26.3	134.7	251.7	1032.1	1536.6	7582.39	7137.8	444.6
Monte Alegre de Minas	2183.3	1165.7	1105.4	121.2	71.7	23.0	3.6	14.9	157.9	340.6	1120.3	1866.0	8173.50	7781.2	392.3
Ponte Meia	1406.0	1200.8	1110.7	294.3	111.5	27.9	1.3	17.3	178.5	287.0	1139.5	1392.7	7167.40	6536.6	630.8
Brilhante	2026.6	1148.3	1157.7	114.0	68.9	25.2	0.9	11.0	169.9	196.9	972.0	2182.7	8074.18	7684.3	389.9
Corumbazul	1940.8	865.5	1148.1	188.6	96.0	24.0	5.1	3.0	88.3	319.2	825.2	1202.0	6705.82	6300.8	405.0
Average	**1848**	**1129**	**1027**	**151**	**91**	**29**	**2**	**17**	**141**	**281**	**1009**	**1646**	**7371.3**	**6940.0**	**431.3**

4 - Conclusions

The EI30 index corresponding to the 30-year period from 1973 to 2002 was 7.880 MJ mm ha^{-1} h^{-1}, which decreased through the three decades studied separately.

In the rainy season, which extends from October to March and during which soil is cultivated, the highest erosion potential occurs: 85% to 88 % of the rainfall and 93% to 95.8% of he annual EI30 are concentrated in this period.

The highest erosivity indexes always occurred next to the Brilhante rainfall station, whereas the lowest indexes occurred close to the fazenda Cachoeira Pouso Alegre station.

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