GROUND'2004 *International Conference on Grounding and Earthing*
&
And *1st International Conference on*
1st LPE *Lightning Physics and Effects*
Belo Horizonte - Brazil November, 2004

NATURAL FIRES OCCURRENCES IN THE CERRADO (BRAZILIAN SAVANNA): CASE STUDY IN THE EMAS NATIONAL PARK, GOIÁS STATE, BRAZIL

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Abstract - The Cerrado biome occupies 25% of the Brazilian territory – approximately 2 million km² – and both its geographical distribution and evolutionary history was largely determined by fire. Presently, the largest part of the burnings in the Cerrado are of human origin, and they occur during the dry season. Nevertheless natural burnings originated by lightning are seldom. The importance of these events in the ecological processes of the Cerrado has almost not been studied. A Geographic Information System and images of CBERS-2 satellite were used to map and quantify the natural burnings which occurred during the rainy season 2003-2004 in the Emas National Park (ENP). The lightning data was collected by the Integrated National Lightning Detection Network – RINDAT. During the 7 months of observation, 14 burnings were mapped, all of them originated by lightning, totalling 5,345 ha (4% of the area from the ENP). The size of the burned areas varied between 1 and 1,759 ha, but in 6 areas the firebreaks influenced on the final dimensions. During the same time 973 cloud-to-ground lightning flashes were detected in the ENP, with a monthly maximum in October (237 lightning flashes, 24.4% of the total). The lightning ignition efficiency was ~1.4%. The spatial analysis presented a higher probability density of lightning occurrence on the top of the plateau and a lower probability at the lower relief sections within the ENP. The results proved that natural burnings are frequent and that they can be important for the conservation of the remnants of Cerrado vegetation.

1 – INTRODUCTION

The Cerrado encompasses an area of around 2 million km² of Brazilian territory and it occurs mainly on the Central Plateau of the country — Figure 1. Occupying almost 25% of the area from Brazil, it is the second largest biome in extension, smaller only than the Amazon Forest. The factors which determine the distribution of Cerrado vegetation are still under controversy among specialists, but the burning regime is considered one of the most important. Cerrado vegetation was exposed to selective fire pressure during its historical evolution. There are evidences of natural burning occurrences at 32,000 years before present (BP), even before human occupation at the Central Plateau [1,2]. After human population occupied this region, around 12,000 years BP, the burning regime was changed, increasing its frequency and time of year when they were done [3]. Most Cerrado plants are adapted to fire, and there are species which are not only adapted but also dependent on it [4]. Evidences of fires caused by lightning are well known and documented in several biomes around the World, such as at the boreal temperate forests [5]. In Canada for instance burnings affects 2.5 million ha yearly and 85% of it is due to fires originated from lightning flashes [6]. Nevertheless in the scientific literature of Cerrado, present burning occurrences are considered as due exclusively to humans [7]. The existence of natural burnings and its ecological implications are almost not considered anymore. Presently it is unquestionable that most wildfires in the Cerrado occur during the dry season and have anthropic origin, related to practices of pasture management and agriculture, as well as to new clearings of occupation fronts. However there are evidences that natural fire events are not so rare and that they can play a fundamental role in the Cerrado conservation [8,9,10]. The only studies on natural burnings in the Cerrado were done at the ENP in South-West Goiás State, Brazil [9,10].

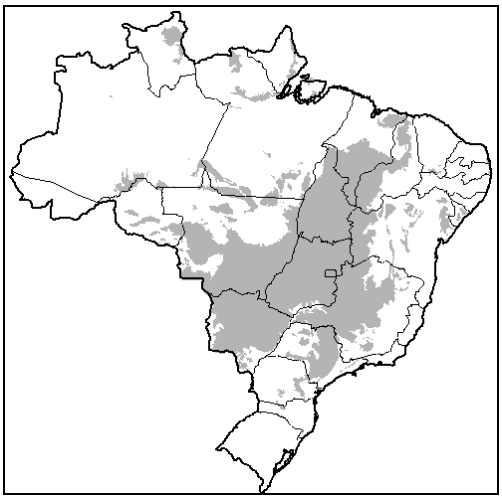

Figure 1 – Location of the Cerrado – Brazilian Savanna.

The objectives of this study were: a) to quantify the incidence of lightning flashes and to analyse its spatial distribution at a savanna Conservation Unit during the rainy season 2003-2004, and b) to map and quantify burnings caused by lightning during the same time period.

2 - BASIC CONSIDERATIONS

The area under study was the ENP, at SW Goiás, located between geographical coordinates S 17º51' to S 18º20' and W 52°44' to W 53°07' — Figure 2.

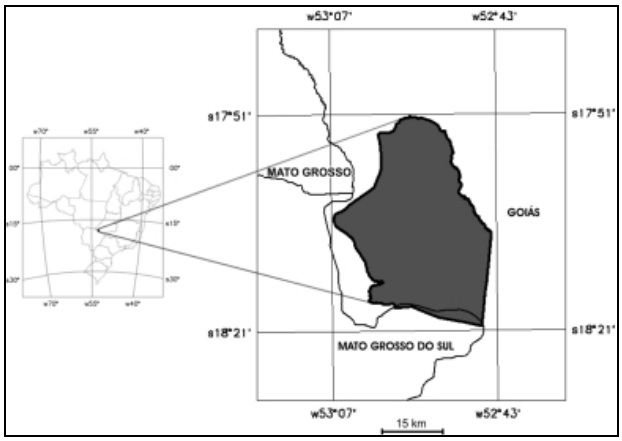

Figure 2 – Location of the Emas National Park.

ENP has a size of 133,000 ha and its historical record of burnings in the last 30 years is well documented [11, 12]. Large wildfires of human origin were frequent until 1994 but after 1995 effective measures were taken against fire from human origin. Since then, almost all burning inside the ENP was originated from lightning.

The largest section of the Park is located over a plateau, with predominantly flat relief and altitudes varying between 800 and 900 m. The climate is tropical warm sub-humid with yearly average temperatures around 22ºC. The rainfall regime defines a wet season, from October to April and a dry season from June to August. May and September are a transition months. Open fields of *cerrado* (*"campos limpos" and "campos sujos"*) occur mainly on the top of the plateau and cover around 80% of the ENP. The remaining area is covered by wet fields, *Buriti* palm sections (*"veredas"*), "*Murunduns"* fields and forests.

The ENP has firebreaks at its outer borders but also an internal net. These firebreaks are kept clean annually since 1995, and totalize ~380 km.

Lightning data were collected from RINDAT, and after 2002, when INPE installed a sensor in city of Campo Grande, it covers the ENP area with a reasonable precision and efficiency. The data were processed in order to allow a better qualification of information, taking into account possible delays of communication and gain variation of the sensors. However they were not corrected by the efficiency of the system, since it is not yet well defined for the region under study.

A preliminary study for the localization of lightning strikes and natural burnings within the ENP was done for the rainy season of the earlier year (2002-03). Totally 1,184 cloud-to-ground lightning strikes and 13 natural burnings were detected between October 1st 2002 and March 31st 2003. The total area burned in this period was of 37,400 ha [10].

3 – DEVELOPMENTS

The following materials were used:

- daily data of localization of cloud-to-ground lightning flashes in the period from 01 October 2003 to 30 April 2004 at geographical coordinates W 52^{o}35´ to W 53^{o}15´ and S 17^{o}40´ to S 18^{o}28', collected by RINDAT;
- CCD/CBERS (China-Brazil Earth Resources Satellite) images, bands 2 (0,52-0,59μm), 3 (0,63-0,69μm) and 4 (0,77-0,89μm) from the following dates: 12 November 2003, 21 March 2004, 12 May 2004, 07 June 2004;
- images from WFI/CBERS-2 bands 1 and 2 from the following dates: 12, 15 and 21 November 2003, 14 December 2003, 27 February 2004, 21 and 27 March 2004, 13, 16 and 22 April 2004, 12 May 2004 and 07 June 2004;
- Quick-look of TM-Landsat-5 image from 25 September 2003;
- Geographic Information System (GIS);
- GPS (Global Positioning System).

A data bank was created at the GIS with the limits of the Park, river, road and firebreak nets and CBERS-2 images. Data of lightning were processed and transferred to the GIS, and the results were daily maps of points corresponding to the localization of lightning strikes which reached inside the ENP. Afterwards monthly maps were created as well as a final map, containing all data referring to the time span studied. The lightning quantified for the monthly total and for all the period and its distribution was analyzed spatially using the quadratic Kernel function [13]. A numerical grid on the probability density of lightnings at the ENP and surroundings was generated, and based on it, an image was created.

The CBERS images were interpreted visually to identify and delimit those burnings occurred during the rainy season 2003-04, according to a methodology proposed by França and Setzer [11,12]. Finally a field survey was done for the confirmation and delimitation of some burnings. The date of burnings, when available, was obtained from the records at ENP and from employees and researchers. Furthermore, when possible, the approximate time of burning occurrence was determined by the observations of sequential TM-Landsat and CBERS images.

A map of burnings was generated and the area of each one was calculated. Finally the maps of burning and probable periods of its occurrence were compared with the corresponding localization of lightning flashes, attempting to identify the probable event that started the fire. In order to do that, just those lightning were considered which were localized inside each burned polygon mapped or at a distance of till 2 km from them.

In this first analysis, the ellipse of error in the location of the flashes was not taken into account.

4 - RESULTS

The period studied covered 212 days, when 973 cloud-to-ground lightning flashes were detected inside the ENP, with an average of 4.6 lightning/day and a flash density of 0.7 flashes/km^2 per year — Table 1 and Figure 3.

Month/Year	No. of lightning	% of lightning
Oct./2003	237	24.4
Nov./2003	89	9.2
Dec./2003	114	11.7
Jan/2004	100	10.3
Feb/2004	135	13.8
Mar/2004	189	19,4
Apr/2004	109	11.2
Total	973	100

Table 1 - Number of lightning flashes inside the ENP.

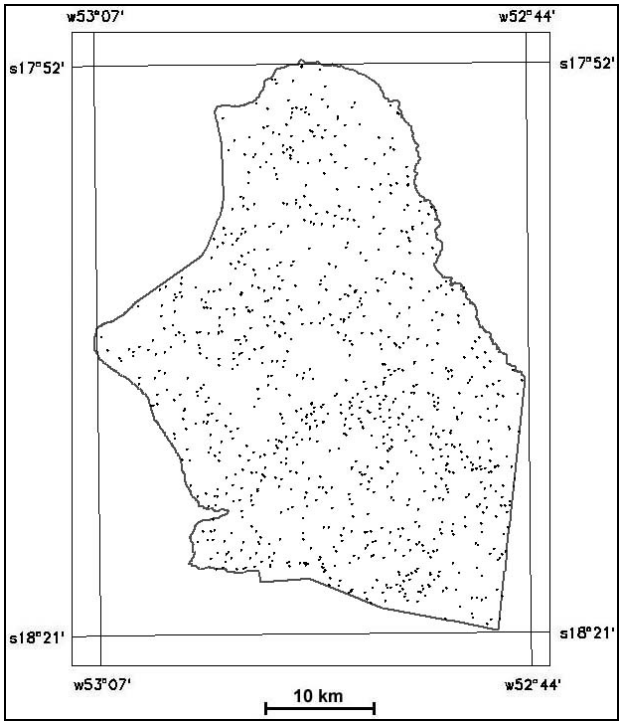

Figure 3 – Location of the lightning strikes in the ENP.

A Kernel function was applied to those points corresponding to the localization of lightning flashes in the ENP and its surroundings. A grid with 300 m of spatial resolution was generated and the number of lightning strikes counted in a radius of 5 km starting from the center of each cell resulted in a map of density of occurrence probability of the event lightning within the ENP — Figure 4.

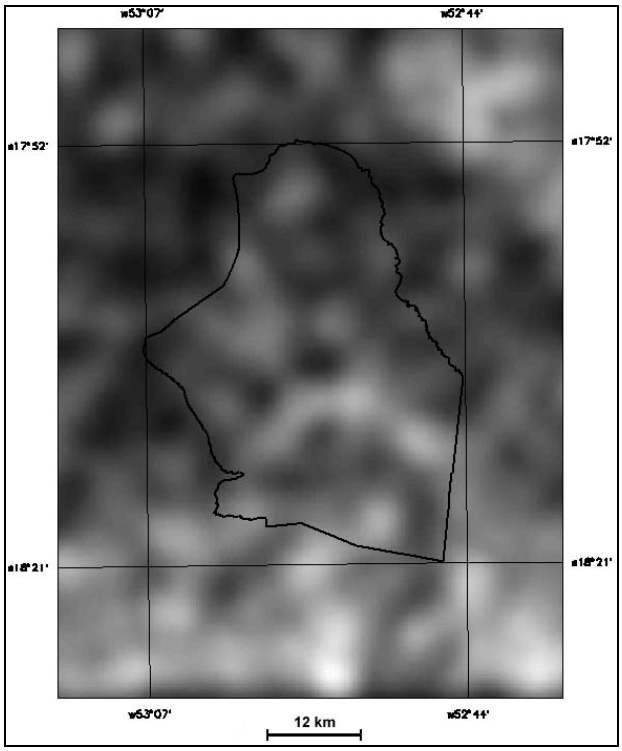

Figure 4 - Probability density of lightning occurrence at the ENP. The black color indicates lower probability (absence of lightning in a radius of 5 km); the white color indicates the highest probability (2.0 lightning in a radius of 5 km) and the gray tones indicate intermediate values.

Fourteen natural burnings were observed in the ENP during the period under study, totaling 5,345 ha (4% of ENP). As for the size of the natural burnings, they vary between 1 and 1,759ha – Table 2 and Figure 5.

Burning	Area (ha)	Period of occurrence (images)	Date of occurrence (field)	No. of lightning
1	2	before 12/Nov/2003		2
2	2	before 12/Nov/2003		2
3	6	before 12/Nov/2003		2
4	1	before 12/Nov/2003		3
5	4	before 12/Nov/2003		4
6	49	before 12/Nov/2003	05/Oct/2003	5
7	143	before 15/Nov/2003	21/Oct/2003	0
8	1,341	21/Nov–14/Dec/2003	28/Nov/2003	3
9	38	21/Nov–14/Dec/2003	27/Nov/2003	2
10	1,759	before 21/Mar/2004	02/Oct/2003	nc
11	2	before 21/Mar/2004		nc
12	353	27/Mar–13/Apr/2004		1
13	2	16/Apr–12/May/2004		4
14	1,643	22/Apr–12/May/2004	23/Apr/2004	2
Total	5,345			

Table 2 – Area and probable dates of natural burnings occurrences in the ENP (nc = not calculated).

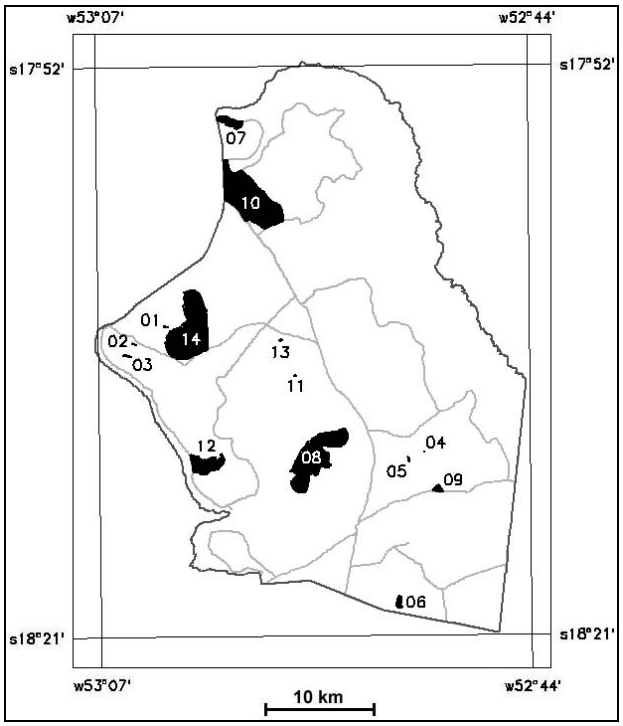

Figure 5 – Natural burnings occurrences in the ENP from October 2003 to April 2004.

5 - ANALYSIS OF THE RESULTS

The absolute number of lightning flashes detected inside the ENP (973) was less than that one found in a similar time span during the year before, when 1,184 flashes were detected between October 2002 and March 2003 [10]. For comparison purposes, the month of April 2004 was not considered. In this case, the number of flashes in the rainy season 2002-03 was almost 1,4 times bigger than in 2003-04. As a consequence, the average quantity of flashes per day in this time span was also lesser: 4.7 flashes/day (6.9 in the earlier period), as well as the density of 0.6 flashes/km^2 (0.9 in the earlier period). All these values are below the national and regional average of 5-10 flashes/km^2 per year, indicating that the efficiency of RINDAT in the region shall be considered in future analysis. Although the detection of lightning in the ENP was not done for a complete one year period, we don't expect that the values obtained would increase much, because the missing months correspond to the dry season, when there are almost no storms and lightning in the region. The results indicate inter-annual variations on the number of lightning flashes in the ENP during the rainy season. The comparison of these values with meteorological data could contribute to better understand the regime of lightning within this park.

The month of October had most incidence of lightning – 24.4% from the total amount – (or 27.4% when disregarding April 2004), agreeing with the observations presented in the time span of the previous study, when 33% of the lightning flashes detected, also occurred in the month of October. If this tendency is confirmed by observations in the coming years, it is possible that in October the probability of natural burning occurrences is really higher than during other months. And the cause would not be only a higher incidence of lightning but also more favorable conditions to burning, when compared with observations of subsequent months, still more humid. Besides that, there is burnable material available, as a result of dry vegetation which accumulated during the previous months, favoring the start of a burning. Nevertheless it is necessary to analyze data referring September, when there are already storms and lightning and the vegetation is still drier than in October.

The application of a Kernel function indicated that the density of occurrence probabilities of lightning within the ENP is not uniform: the highest values were found on the top of the plateau and the lowest in lower sections, along Jacuba River at the northern and northeastern border of the Park. However, since the data used were only from one rainy season, the results allowed just to characterize the spatial distribution of the lightning during the time span under consideration.

Fourteen natural burnings were observed in the ENP during the period under study, totaling 5,345 ha (4% of ENP). In the earlier rainy season, the area attained by the 13 natural burnings was of 37,400 ha (28% of ENP). It is probable that the difference in the total areas burned during both seasons was determined by meteorological conditions after the start of the fire. Nevertheless the lack of meteorological data and of precise dates of burning occurrences impede that this hypothesis is examined.

The size of the natural burnings varied between 1 and 1,759ha. The final size of the burnings could have been determined by meteorological conditions and also by the availability of burnable material. The availability of this material is related with the physiognomy of vegetation and the historic record of recent burnings in this place. However the size of many natural burnings has human influence, because frequently they are hindered by the firebreaks.

It was not possible to identify individually those lightning strike which started the burnings, but only to localize those which are the most probable — Table 2. The absence or missing of confidentiality on information from dates and times of the start from the burnings was the main impediment to make this identification.

6 - CONCLUSIONS

Normally it is considered that the burnings of Cerrado vegetation are always of human origin and that they occur during the dry season. This study contributed to show that burnings originated by lightning are frequent during the rainy season in the ENP. These burnings occur annually and they create a mosaic of areas with different ages and phenologic stages of vegetation related to the last burning. This configuration impedes the propagation of burnings over a wide area, acting as large natural barriers to large burnings. Besides that, it favors the diversification on the offer of resources and of shelter for the fauna. The fire, which was always considered as a threat to conservation, can effectively become an ally, if

research and monitoring is done to determine the best form to manage it. The comprehension of the natural regime of burnings can result in techniques of management directed towards the conservation of Cerrado remnants, especially in the Conservation Units.

Taking into account that 65% of Cerrado area was totally or partially degraded and this biome contains one of the largest indices of world biodiversity, a priority must be given to research directed towards its understanding and conservation.

Within this context, besides proceeding with the studies of natural burnings in the ENP, we recommend to extend them also to other protected areas where burnings of human origin are rare or inexistent. It is important to install an automatic fire detection system in those areas under study, in order to obtain reliable information about the date, time and location of the start of a burning. In this way, the relation between the incidence of lightning and the occurrence of fire in Cerrado vegetation can be better quantified and understood. The collection of meteorological data in those places under study must also become a priority, because they are of fundamental importance to evaluate the conditions of burnable vegetation and of fire propagation.

7 – REFERENCES

[1] LABORIAU, M.L.S.; CASSETI, V.; VICENTINI, K.R.F.; MARTIN, L.; SOUBIÈS, F.; SUGUIO, K.; TURQ, B. "Late quaternary and climatic changes in cerrado and palm swamp from central Brazil". *Paleogeography, Paleoclimatology, Paleoecology*, 128: 215-226, 1997.

[2] MIRANDA, H.S.; BUSTAMANTE, M.M.C.; MIRANDA, A.C. "The fire factor". In: MOREIRA, P.S.; MARQUIS, R.J. (ed.). *The Cerrados of Brazil: Ecology and Natural History of a Neotropical Savanna.* New York, Columbia Univ. Press, pp. 52-68, 2002.

[3] HOFFMANN, W.A.; MOREIRA, A.G. "The role of fire in population dynamics of woody plants". In: MOREIRA, P.S.; MARQUIS, R.J. (ed.). *The Cerrados of Brazil: Ecology and Natural History of a Neotropical Savanna.* New York, Columbia Univ. Press, pp. 159-177, 2002.

[4] OLIVEIRA-FILHO, A.T.; RATTER, J.A. "Vegetation physiognomies and woody flora of the Cerrado biome". In: MOREIRA, P.S.; MARQUIS, R.J. (ed.). *The Cerrados of Brazil: Ecology and Natural History of a Neotropical Savanna.* New York, Columbia Univ. Press, pp. 91-177120, 2002.

[5] WHELAN, R. "*The ecology of fire.*" Cambridge University Press. Cambridge, 1995

[6] CANADIAN FOREST SERVICE. http://fire.cfs.nrcan.gc.ca/facts_e.php

[7] MISTRY, J. "Fire in the cerrado (savannas) of Brazil: an ecological review". *Progress in Physical Geography*, 22(4):425-448, 1998.

[8] COUTINHO, L.M. "Fire in the ecology of the Brazilian cerrado". In: Goldammer, J.G. (ed*.). Fire in the tropical biota.* New York, Springer-Verlag, pp.82-105, 1990.

[9] RAMOS-NETO, M.B. "*O Parque Nacional das Emas (GO) e o fogo: implicações para a conservação biológica"*. Tese de doutoramento. Instituto de Biociências da Universidade de São Paulo. São Paulo, 2000.

[10] FRANÇA, H.; PEREIRA, A.; PINTO JR, O.; FERNANDES, W.A.; GOMEZ, R.P.S. "Ocorrências de raios e queimadas naturais no Parque Nacional das Emas, GO, na estação chuvosa de 2002-2003" IV Congresso Brasileiro de Unidades de Conservação .Anais. Curitiba, Brazil , Outubro 2004. (Accepted.)

[11] FRANÇA, H.; SETZER, A. *Regime de queimadas no Parque Nacional das Emas: 1973-1995.* Relatório de Pesquisa FAPESP. INPE, São José dos Campos, 1997.

[12] FRANÇA, H.; SETZER, A. "A história do fogo no Parque das Emas". *Ciência Hoje* 26(153): 69-73, 1999.

[13] DIVISÃO DE PROCESSAMENTO DE IMAGENS-Instituto Nacional de Pesquisas Espaciais. http://www.dpi.inpe.br/spring, 2004.

[14] PINTO JR. O.; PINTO, I.C.A. *Tempestades e relâmpagos no Brasil*. São José dos Campos, INPE, 2000.

[15] MANTOVANI, J.E.; PEREIRA, A. "Estimativa da integridade da cobertura vegetal do Cerrado através de dados TM/Landsat". *9º Simpósio Brasileiro de Sensoriamento Remoto Anais*. Santos, Setembro1998. CD-ROM.

[16] CAVALCANTI, R.B.; JOLY, C.A. "Biodiversity and conservation priorities in the Cerrado region" In: MOREIRA, P.S.; MARQUIS, R.J. (ed.). *The Cerrados of Brazil: Ecology and Natural History of a Neotropical Savanna.* New York, Columbia Univ. Press, pp. 351-367, 2002.

[17] MYERS, N.; MITTERMEIER, R.A.; MITTERMEIER, C.G.; FONSECA, A.B.; KENT, J. "Biodiversity hotpots for conservation priorities". *Nature* 403, pp.853-858.

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