

Deforestation and burning of the Cerrado (Brazilian savanna) in the Uruçuí-Una Ecological Station, Brazil, based on CCD/CBERS-2 and TM/Landsat-5 images from 2003 to 2008

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Abstract. In this study I analyzed the dynamics of the deforestation and burning during the dry season from 2003 to 2008 in the Uruçuí-Una Ecological Station and its buffer zone, in Piauí, Brazil, based on images of the orbital sensors CCD/CBERS-2 and TM/Landsat-5. The deforested areas were expanded through all dates analyzed and were larger in the buffer zone, suggesting a relative protection of the ESECUU. New cut-offs were predictable because of the early opening of roads that would become their limits. The burning scars were larger in the end of the dry season in consequence of the anthropic burnings for the management and implementation of agricultures and pastures. In 2004 and 2007 these scars were considerably larger probably because of the increase of dry biomass that every three years is big enough to spread through the native vegetation the fire originated in agricultures and pastures. This scenario reaffirms the needs for: a stronger enforcement in order to stop the anthropization in the ESECUU; a management plan, absent for this unit so far; and the admission of new employees since there had been only one until 2004. Cerrado is one of the largest biomes in Brazil and its size and biodiversity justify its importance. However, anthropogenic interferences risk its integrity, as can be noticed in the results of this research. It is expected that studies like this will offer subsidies for the proper management of conservation areas in this biome and for the implementation of new ones.

Palavras-chave: anthropization, ESEC Uruçuí-Una; Piauí; remote sensing.

1 Introduction

Cerrado, or “chaco”, is a type of savanna that occurs in Brazil, Paraguay and Bolivia. It’s one of the largest Brazilian biomes and extends from the northeastern coast, through the center of the country, until the western region (IBGE, 2004). It’s original domain represents 21% of the national territory, approximately 2 million km², however at least 65% percent of it has already been modified because of anthropization (Mantovani and Pereira, 1998; Machado *et al.*, 2004). Studies on this biome are important for the maintenance of the biodiversity and because it is the habitat of many endemic and migratory species that are at risk of extinction (Zaher, 2001; Mantovani and Pereira, 1998; Aguiar *et al.*, 2004).

Fire is one of the most important ecological features of the cerrado, which can be started naturally or by the interference of man (França and Setzer, 2001; França *et al.*, 2007). In the rainy season, from October to March, lightnings occasionally start fire during rainstorms and, in this case, areas don’t usually burn more than 1km² (França *et al.*, 2007). However, man has been the principal cause of fire in the cerrado from the earliest times (Coutinho, 1990), specially during the dry season, from April to September, when farmers burn areas for agriculture and cattle raising and the fire is spread through hundreds of kilometers of the cerrado, in this case, with no rain to stop it (Coutinho, 1990; França *et al.*, 2007).

The objective of this study is to quantify the deforestation and burning dynamics during the dry season from 2003 to 2008 in the Uruçuí-Una Ecological Station (ESECUU) and its buffer zone using orbital images of the sensors CCD/CBERS-2 and TM/Landsat-5. This conservation area should provide protection to its ranges of cerrado, spring waters, rivers and fauna. But the

truth is its delicate natural equilibrium is endangered because of anthropization. Burning and the deforestation of large areas outside of the station, by farmers, and inside by “posseiros” (squatters) to promote agriculture and cattle raising are the biggest dangers to the ecosystems there (Zaher, 2001, IBAMA, 2004).

2 Methodology

The study area is the Uruçuí-Una Ecological Station and its buffer zone. This conservation area is located in Baixa Grande do Ribeiro city, Piauí, Brazil (Brazil, 1981). Buffer zone is the area evolving every Conservation Unit – among these Ecological Stations. It covers the 10km extension from the borders of these Units and its use is restricted (Brazil, 1990). The ESECUU limits are between latitudes 8°30’S and 9°11’S and longitudes 44°50’W and 45°40’W. The ESECUU is 203,426.91 ha, its buffer zone, 239,375.34 ha, and the sum of both areas is 442,802.25 ha

2.1 Material

In this study we used the geoprocessing softwares SPRING 4.3.3 (INPE a, 2008) and ENVI 4.3 (ITT, 2008), the ESECUU limits (IBAMA, 2004), 15 CBERS and Landsat images (INPE b, 2008) and one Landsat Geocover image of August 30th, 2001 (NASA, 2008). The images used are listed on Table 1, two for each year: one in the middle of the dry season and one in the end.

Table 1 – Dates, sensors, orbits/points and color composites used. MD indicates dates in the middle of the dry season (light-grey shaded) and ED in the end. Asterisks mark the images that don't cover the study area and the support images are underlined.

Date	Sensor	Path/Row	Composite
27/07/2003 (MD)	TM/Landsat-5	220/66	3B4R5G
16/11/2003 (ED)	TM/Landsat-5	220/66	3B4R5G
13/07/2004 (MD)	TM/Landsat-5	220/66	3B4R5G
17/10/2004 (ED)	TM/Landsat-5	220/66	3B4R5G
20/07/2005 (MD)*	CCD/CBERS-2	156/110	2G3B4R
17/07/2005 (MD)	CCD/CBERS-2	157/110	2G3B4R
06/10/2005 (ED)*	CCD/CBERS-2	156/110	2G3B4R
07/09/2005 (ED)	CCD/CBERS-2	157/110	2G3B4R
19/07/2006 (MD)	TM/Landsat-5	220/66	3B4R5G
14/08/2006 (ED)*	CCD/CBERS-2	156/110	2G3B4R
09/09/2006 (ED)	CCD/CBERS-2	156/110	2G3B4R
22/07/2007 (MD)	TM/Landsat-5	220/66	3B4R5G
24/09/2007 (ED)	TM/Landsat-5	220/66	3B4R5G
08/07/2008 (MD)	TM/Landsat-5	220/66	3B4R5G
26/09/2008 (ED)	TM/Landsat-5	220/66	3B4R5G

The images of 2005 didn't cover the whole study area and clouds didn't allow vision of parts of the study area in the end of the dry season of 2006. Consequently three extra images were necessary. July images were available for all the years. However, the same wasn't true for the end of the dry season dates. So we choose the ones dating closer to October, which varied from August to November, depending on the year.

The bands of the orbital sensor CCD/CBERS-2 were 2 (0,52-0,59 μm), 3 (0,63-0,69 μm) and 4 (0,77-0,89 μm), with geometric resolution of 20 m. And from TM/Landsat-5 were bands 3 (0,63-0,76 μm), 4 (0,76-0,90 μm) and 5 (1,55-1,75 μm), with geometric resolution of 30 m.

2.2 Methods

The images were georeferenced to the Geocover image using ENVI 4.3 and all the following proceedings were made using SPRING 4.3.3. In addition to the images, the ESECUU limits were imported to this software and a layer with the limits of the buffer zone was created (Figure 1).

Four thematic layers for each image were created using visual interpretation and raster edition: deforestation in the ESECUU, deforestation in the buffer zone, burning scars in the ESECUU and burning scars in the buffer zone. For deforestation we made a sequential interpretation starting from the first image of 2003, with the generation of a layer that was copied to the layer of the next date and edited according to the interpretation of this new date. The burning scars layers were created by a sequential interpretation as well, but they were independent from the previous dates.

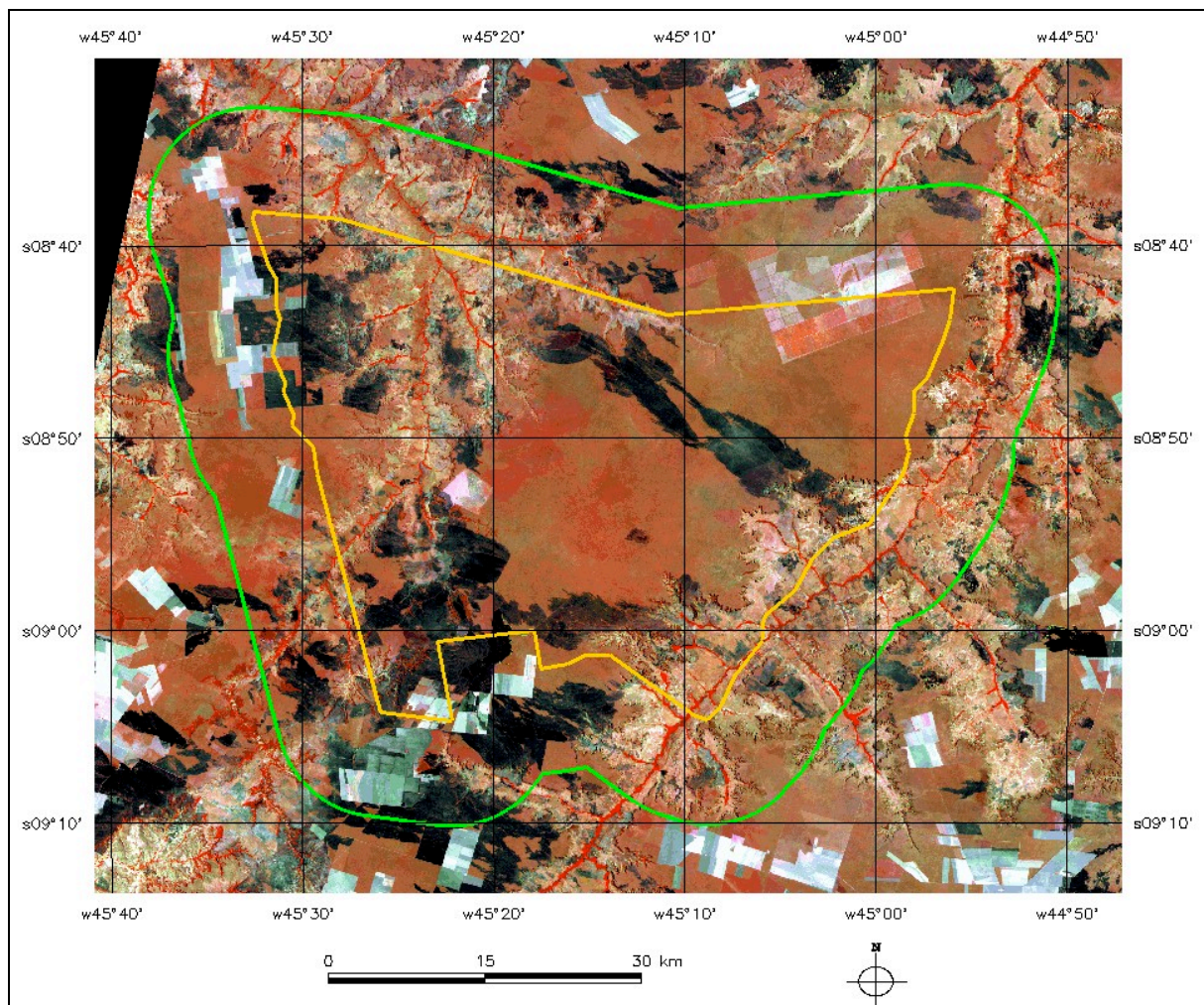


Figure 1: False-color composite band 3(B), band 4(R) and band 5(G) of the orbital sensor TM/Landsat-5. Acquisition: September 24th, 2007. The Uruçuí-Una Ecological Station is within the yellow frontiers and the buffer zone is on the outside of the Station until the green limits.

Fundamental elements of the images like color, texture, shape, size, shade and location were visually interpreted for the detection of the deforested and burned areas on the false-color

composites. The main characteristics of the deforestations were the squared shape and the colors: cyan when bare soil, and light-red or brown when agriculture and pastures. The burning scars were detected mainly for their irregular shape and characteristic colors. They were black when new, cyan after sometime, and at last brown or light red (agricultures and pastures), or dark-red (re-growth of native vegetation). Some regions, not used after deforestation and burnings, were considered deforested or burned until the re-growth of the vegetation became dark-red: equal to the surrounding native cerrado.

3. Results and Discussion

In the ESECUU, buffer zone and both analyzed together the deforested areas were expanded through all dates and were a lot larger in the buffer: at least twice or 3 times as much. (Table 2 and Figures 2, 3 and 4). This fact indicates a relative protection of the ESECUU probably because farmers might give preference to deforest outside the preservation area in order to avoid legal problems.

Table 2: Area (ha) and percentage deforested of the Uruçuí-Una Ecological Station (UU), its buffer zone (BZ), and both areas together (UU+BZ), in the middle of the dry seasons (MD), and in the end of the dry seasons (ED).

Date	Deforestation					
	UU		BZ		UU+BZ	
	ha	%	ha	%	ha	%
Jul/03 (MS)	11,093.22	5,45	24,030.90	10,04	35,124.12	7,93
Nov/03 (FS)	11,110.23	5,46	24,341.22	10,17	35,451.45	8,01
Jul/04 (MS)	13,183.65	6,48	34,017.75	14,21	47,201.40	10,66
Oct/04 (FS)	13,202.19	6,49	34,674.93	14,49	47,877.12	10,81
Jul/05 (MS)	13,623.40	6,70	37,907.76	15,84	51,531.16	11,64
<u>Jul/05 (MS)</u>	Support to the July 20 th , 2005 image (above).					
Oct/05 (FS)	13,627.80	6,70	38,168.08	15,94	51,795.88	11,70
<u>Sep/05 (FS)</u>	Support to the October 06 th , 2005 image (above).					
Jul/06 (MS)	13,691.70	6,73	38,674.62	16,16	52,366.32	11,83
Aug/06 (FS)	13,778.28	6,77	38,781.36	16,20	52,559.64	11,87
<u>Sep/06 (FS)</u>	Support to the August 14 th , 2006 image (above).					
Jul/07 (MS)	13,847.85	6,81	40,181.22	16,79	54,029.07	12,20
Sep/07 (FS)	13,865.82	6,82	40,233.90	16,81	54,099.72	12,22
Jul/08 (MS)	17,861.76	8,78	40,986.72	17,12	58,848.48	13,29
Sep/08 (FS)	17,873.19	8,79	41,505.03	17,34	59,378.22	13,41

In Brazil, the biggest expansion of the agriculture and pasture frontiers has happened in the Cerrado (COUTINHO, 1990; SMITH *et al*, 1998, EMBRAPA CERRADOS, 2005). In this study

this expansion was predictable most of the times because of the opening of roads or “aceiros” forming squares that could be observed on the images. Then the native cerrado vegetation inside these polygons were deforested or deforested and burned and at last, new agricultures or pastures would be established. The total deforested areas increased 61% in the ESECUU, 73% in the buffer zone and 69% in both areas analyzed as one, from July 2003 to September 2008.

According to some authors like Coutinho, 1990, Pereira, 1992, França and Setzer (2001) the fire season usually starts in May and peaks by late August and early September. This happens because farmers fire the cerrado in the end of the dry season to clear areas for new agricultures or to use the new vegetation that sprouts after the fire to feed cattle. This practice constitutes the greatest cause of burn-offs in the Cerrado (Coutinho, 1990). In the ESECUU and its buffer zone the burning scars were larger in the end of the dry season comparing to the mid-season dates in all years analyzed (Table 3 and Figures 2, 3 and 4).

França *et al* (2007) studied the fire in Emas National Park, Goiás, Brazil, and observed that after the abolition of anthropic burnings inside this conservation area the dry phytomass increased along the time. Every three years its amount was critical enough to extensively spread through the native vegetation the fire originated in plantations and pastures outside the Park. Although burning scars were detected in all dates analyzed, they were considerably larger in the ESECUU in 2004 and 2007, indicating an interval of three years between big fire events. Since the same is not true considering the buffer zone alone, it’s possible to presume that every three years large areas in the ESECUU are affected by the fire originated in plantations and pastures as well (Table 3 and Figures 2, 3 and 4).

Table 3: Area (ha) and percentage burned of the Uruçui-Una Ecological Station (UU), its buffer zone (BZ), and both areas together (UU+BZ), in the middle of the dry seasons (MD), and in the end of the dry seasons (ED).

Data	Queima					
	UU		ZA		UU+ZA	
	ha	%	ha	%	ha	%
Jul/03 (MS)	3.524,58	1,73	5.874,66	2,45	9.399,24	2,12
Nov/03 (FS)	10.352,88	5,09	35.994,87	15,04	46.347,75	10,47
Jul/04 (MS)	5.846,04	2,87	5.991,93	2,50	11.837,97	2,67
Oct/04 (FS)	70.579,80	34,70	45.556,38	19,03	116.136,18	26,23
Jul/05 (MS)	7.387,08	3,63	23.728,60	9,91	31.115,68	7,03
<u>Jul/05 (MS)</u>	Support to the July 20 th , 2005 image (above).					
Oct/05 (FS)	27.846,20	13,69	48.259,00	20,16	76.105,20	17,19
<u>Sep/05 (FS)</u>	Support to the October 06 th , 2005 image (above).					
Jul/06 (MS)	3.597,40	1,77	11.019,76	4,60	14.617,16	3,30
Aug/06 (FS)	11.032,56	5,42	18.979,02	7,93	30.011,58	6,78
<u>Sep/06 (FS)</u>	Support to the August 14 th , 2006 image (above).					
Jul/07 (MS)	9.493,83	4,67	10.056,51	4,20	19.550,34	4,42
Sep/07 (FS)	60.974,55	29,97	66.258,54	27,68	127.233,09	28,73
Jul/08 (MS)	5.449,86	2,68	14.649,84	6,12	20.099,70	4,54
Sep/08 (FS)	20.504,97	10,08	41.282,01	17,25	61.786,98	13,95

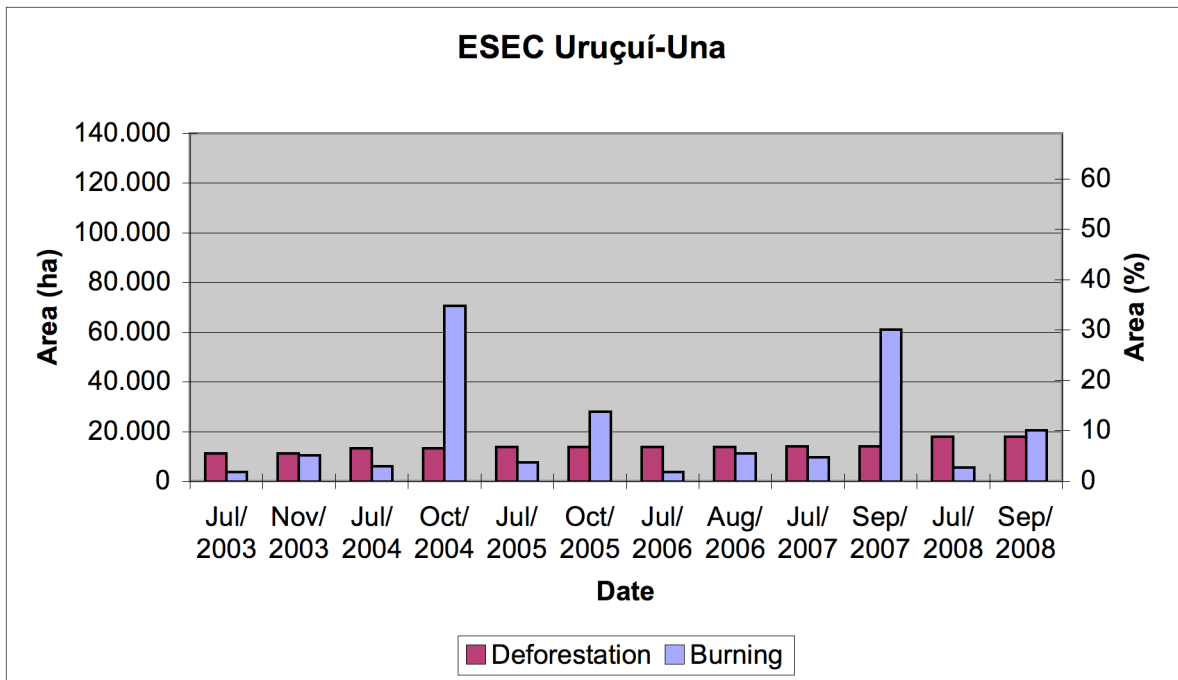


Figure 2: Deforested and burned areas in the Uruçuí-Una Ecological Station, Piauí, Brazil.

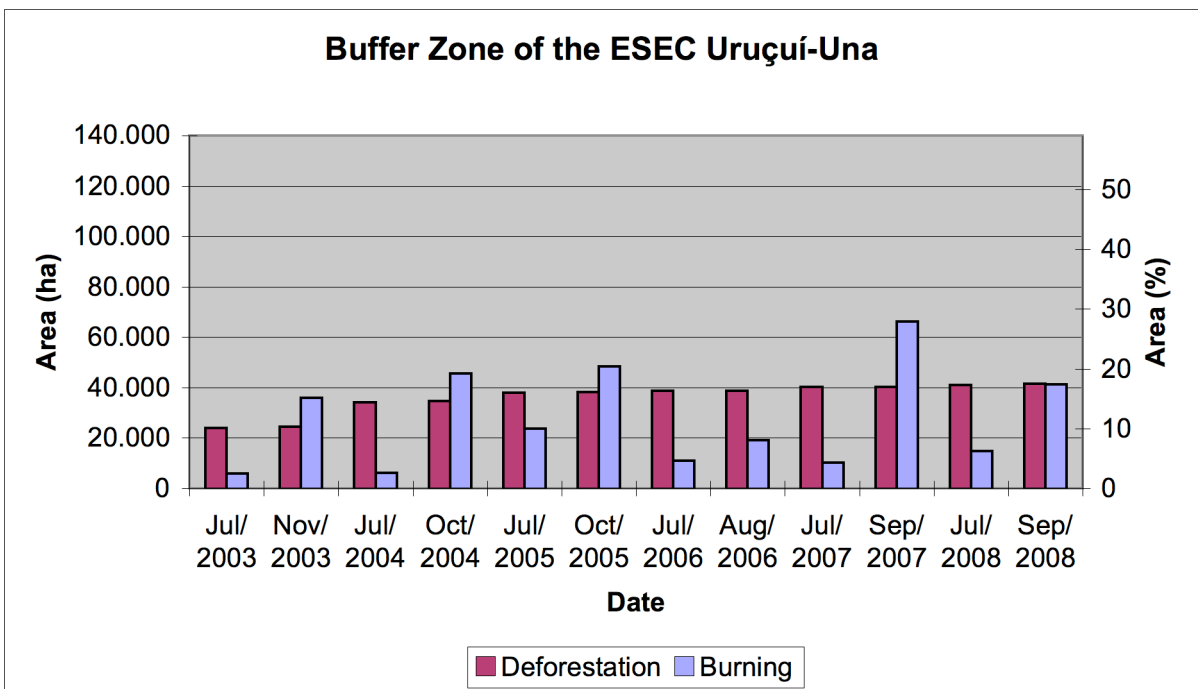


Figure 3: Deforested and burned areas in the buffer zone of the Uruçuí-Una Ecological Station, Piauí, Brazil.

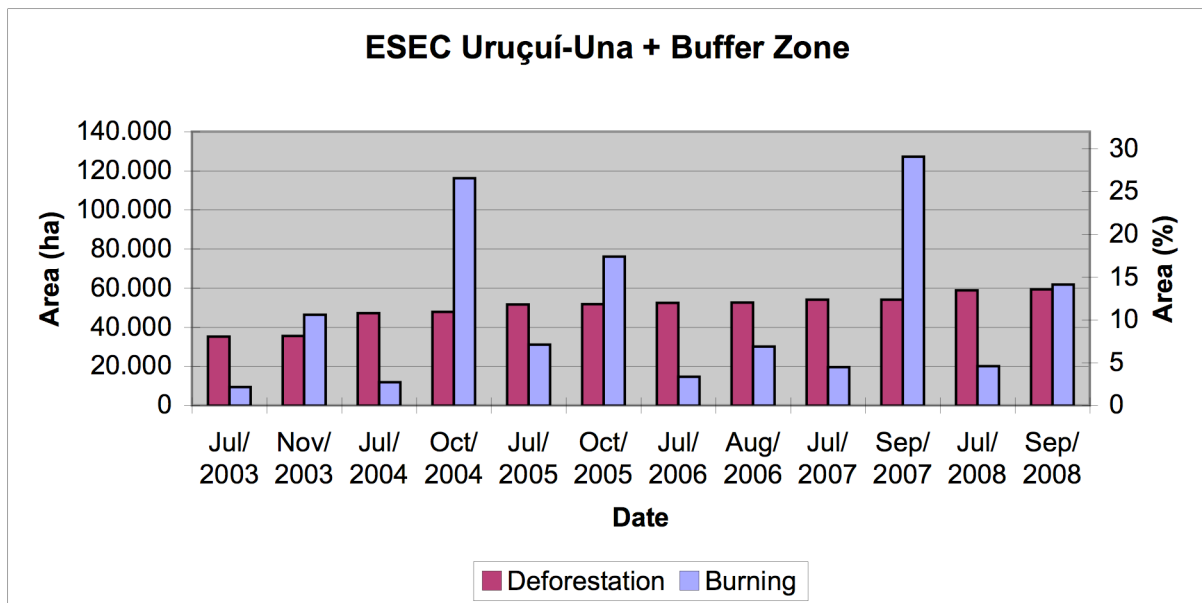


Figure 4: Deforested and burned areas in the Uruçuí-Una Ecological Station and its buffer zone, Piauí, Brazil.

4. Conclusion

The deforested areas were expanded through all the dates analyzed and were even larger in the buffer zone, suggesting a relative protection of the ESECUU. Sometimes the establishment of new cut-offs was predictable because the early opening of roads and “aceiros” that would become their limits could be observed on the images. There were burning scars in both ESECUU and buffer zone on all dates analyzed as well, and they were much larger in the end of the dry season in consequence of the anthropic burnings for the management and implementation of agriculture and pasture areas. Furthermore, these scars were considerably larger in 2004 and 2007 comparing to the other studied years probably because of the increase of dry biomass in the cerrado (Brazilian savanna) that every three years is big enough to extensively spread through the native vegetation the fire originated in plantations and pastures. The scenario described in this study reaffirms the urgent needs: for a stronger enforcement in order to stop the anthropization in the ESECUU; the creation of a management plan, absent for this unit so far; and the admission of new employees since there had been only one until 2004. Cerrado is one of the largest biomes in Brazil and its size and biodiversity justify its importance. However, anthropogenic interferences risk its integrity, as can be noticed in the results of this research. It is expected that studies like the one presented here will offer subsidies for the proper management of conservation areas in this biome and for the implementation of new ones.

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