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Identification and Analysis of Burned Areas in Ecological Stations of Brazilian Cerrado

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1. Introduction

The degradation of the soil and native ecosystems and the dispersion of exotic species are the largest threats to the biodiversity. Brazil is considered one of the most biodiversity countries in the world, where it is concentrated about 10% of whole terrestrial biota (Mittermeier et al., 1997). Studies have shown that the Brazilian diversity was already greater than is recorded nowadays. Even with the disappearance of species, the biodiversity of the Cerrado is still quite expressive and notable. Depending on the taxonomic group, 20 to 50% of species occurring in the Brazilian Cerrado.

The great diversity of species of animals and plants of the Cerrado is associated with spatial heterogeneity (the variation of ecosystems over space) of this biome, which allows the coexistence of different physiognomic forms in the same region. The variation of environments makes possible species of animals and plants present a strong association with local ecosystems, being closely tied to natural environments, such as the *Antilophia galeata* which are found only in gallery forests, and the *Mauritia flexuosa* that are closely associated with the paths. This relation fauna-flora-Cerrado illustrates the importance of maintaining of the natural vegetable covering of this biome, as a basic strategy for maintaining biological diversity expressive.

Recent studies indicate that a loss up to 25% of bird species associated with the gallery forest of the Cerrado may occur, just if there is the destruction of natural environments to the neighboring woods, even though it remains untouched (Machado, 2000; Machado et al ., 2004). Furthermore, excessive reduction of native areas will cause the extinction of species from fragments of small size (Hass, 2002).

The Cerrado is a biome originally covered by vegetation ranging from grassland (country) to *Cerradão* and has two well-defined seasons: dry winter and rainy summer. This biome shelters deciduous species and presents a nutrient-poor acidic soil with high iron and aluminum content. According to Eiten (1979), the Cerrado vegetation varies from sparse trees to dense forest vegetation. The variation in the Cerrado physiognomies has been attributed to the action of fire, soil factors (Eiten, 1972; Coutinho, 1978; Rizzini, 1979), topography and water (Furley & Ratter, 1988).

The Cerrado biome is the second largest biogeographic region of Brazil covering an area of 2,036,448.00 km² (Fig. 1), around 23% of the national territory (Ratter et al., 1997).

Approximately 40% of this biome has already been completely anthropized for agricultural and livestock activities. Such activities may cause serious damage to the Cerrado such as burning, tree felling for charcoal production. Hoffmann & Jackson (2000) affirmed that the conversion of the natural Savannah in pasture can reduce the precipitation in at least 10%, and to increase the medium temperature of the superficial air in 0.5°C. Those practices usually occur in a disorderly and non-sustainable way (Castro, 1999; Saucer, 1999; Araujo, 2005).

Fig. 1. Cerrado biome in Brazil (http://www.wwf.org.br/)

In Piauí state the Cerrado occupies approximately 115,000 km² (larger area of Northeast Brazil), presenting great potential for exploitation. Currently, the state has experienced a rapid occupation and consequently it is estimated that about 10% of this ecosystem have already been occupied by agricultural projects. From the 90's, this process was accelerated by the deployment of mechanized agriculture, especially in grain crops, including soybeans, corn, rice and beans (Araujo, 2005). Agricultural expansion occurs mainly in Southern and Southwestern of Piauí, because they are favoured by stable climate and topography, what consists of large plateaus on the tops of mountains (EMATER, 2009; Funaguas, 2009). The irrational use of this biome is followed by problems such as erosion and the consequent desertification. The last phenomenon has already been detected in this region.
Burning is the most harmful of all these factors. In drought periods, this phenomenon is a matter of constant concern due to use of passive fire protection products. There are two types of burning causes: natural and anthropic. In the first type, burnings usually occur in

areas of dry vegetation, leading to devastating fires; anthropogenic burnings, in turn, may occur in any type of vegetation (Eiten, 1972; Coutinho, 1978).

In Brazil, the main causes of burning in the Cerrado were due to improper use of fire equipment. Some pre-fire characteristics of ecological fires (Whelan, 1997) are not detected at the moment of the burning, as the firebreaks construction, the checking of climatic conditions and of the appropriate period, as well as the availability of fire control equipment. Additionally, criminal fires are frequent, which are caused by the action of arsonists, hunters, fishermen and balloons (Medeiros, 2002).

Great burnings may present serious risks for the conservation of the biodiversity and maintenance of ecological processes. These fires are particularly dangerous in small areas, which present rare species and/or species susceptible to extinction, which are usually very sensitive to the fire. This is the case of most Conservation Units (UC) in Brazil, including the Ecological Stations (ES) where many species are at risk of population decline because of these factors (Dias, 1998).

The geographical location of the fires within an ecological station can be used in strategies to fight fires in this area. A technique that has proven to be efficient is satellite monitoring (Cihlar et al., 1997; Carvalho, 2001; Remmel & Perera, 2001). The relatively low cost and the possibility of easily obtaining digital images have stimulated research on the theme. In digital, orbital or aerial, images it is possible to identify forest fires. Also, by temporary analysis, it is possible to characterize the previous types of vegetations that were destroyed by fires.

In this paper, a multi-temporary series of images of the Landsat 5 (American satellite) was used in the location and dimension of burned areas. Those images cover the area of the Uruçuí-Una Ecological Station (UUES) located in southern Piauí state / Brazil (approximate central coordinate: Latitude 8º52′ and Longitude 45º12′ South). The purpose of this study is to investigate the locations and frequencies of burnings, as well as the type of vegetation damaged by fires, besides analyzing if there is influence of the El-Niño and the La-Niña phenomena.

2. Ecological station

Currently, environmental problems have received special attention, and there has been much discussion on environmental preservation. The establishment of protected areas, called Conservation Units (CUs) emerges from this discussion. The purpose of these CUs is to protect the flora and fauna, by reducing the negative impacts of human activity on biodiversity. In Brazil, the creation of protected areas was legally established by the Brazilian Forest Code (Decree 23.793 - 1934). The first Ecological Park was created only in 1937 (Sick, 1997).

The Conservation Areas are divided into two major groups: Integral Protection Conservation Units (IPU) and Sustainable Use Conservation Units (SUU). The first group aims to balance nature conservation by promoting its sustainable use. The second goal is to preserve the nature, admitting only the indirect use of its natural resources, except in cases provided by Law. The two groups are subdivided into categories. The Ecological Stations belong to the second group.

2.1 Uruçui-Una ecological station

The Uruçuí-Una Ecological Station (UUES), with a total area exceeding 1,300 square kilometers, was established in 1981 with the purpose of protecting and preserving fragments of Cerrado ecosystems and promoting the development of scientific research.

The vegetation cover consists predominantly of UUES *cerrado stricto sensu*, but other types of vegetation, e.g. *campo cerrado* are also found. The *cerrado sensu stricto* in this area is composed of grasslands, with dense cover of grass and low trees.
The UUES located in the plateaux sub-region (scarps that resulted from the erosive action of waters) in the Cerrado of the Southwest of Piauí, within the boundaries of the cities of Baixa Grande do Ribeiro and Santa Filomena, about 730 km from Teresina, the State capital. Fig. 2 shows the location and boundaries of UUES.

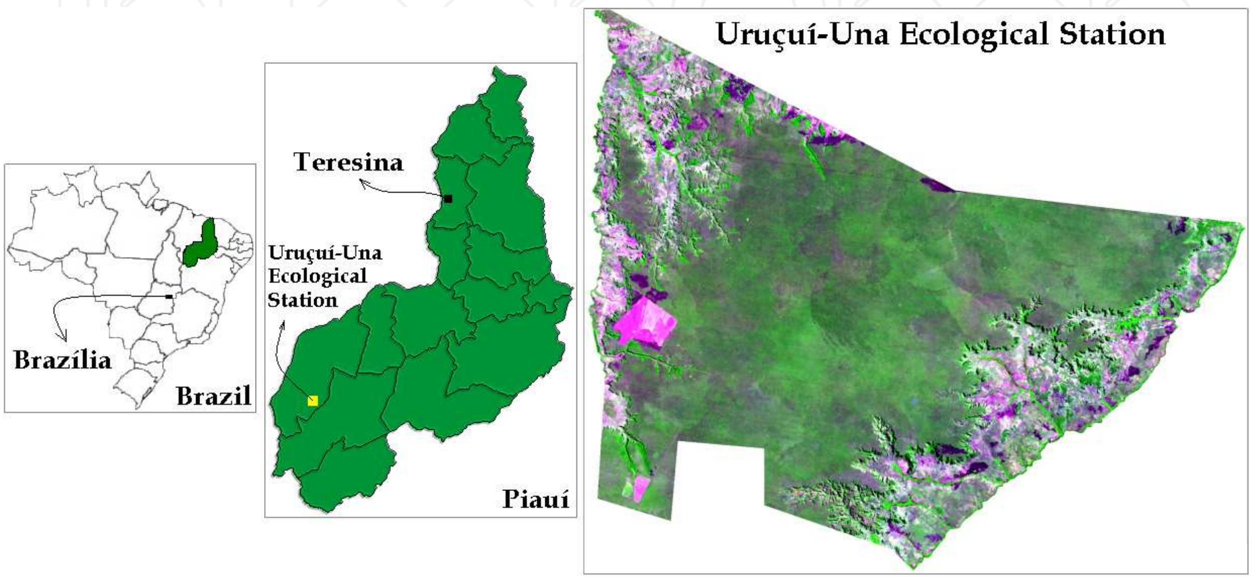


Fig. 2. Location of the Uruçuí-Una Ecological Station

The average altitude of the plateau in the UUES is 620 meters. With a typically tropical climate, this area has high average temperatures, varying between 24 and 26 ºC, with absolute maximum annual reaching 40 °C. The relative humidity of air oscillates between 60 and 84% and the average annual precipitation levels are below 800mm. Regarding its physiography Piaui is a typical zone of transition, i. e., a mixture of biomes such as the *Caatinga*, the *Closed Deciduous Forest* and *Cerradão*. Finally, the aforementioned economies of the two municipal districts are predominantly agricultural, particularly grain production, such as soybean and corn (Medeiros & Cunha, 2006).

3. Forest fire

The fire is usually used to clean lands, e. g. the preparation for planting or pasture. According to Medeiros (2002), a forest fire is a fire that starts in several types of vegetation, running out of control, which can be intentionally started or have natural causes such as sunlight. Large forest fires can be considered a serious threat to biodiversity conservation and the maintenance of ecological processes. This threat is particularly serious for small areas, sections isolated by cities or agricultural monocultures and areas with rare and/or endangered species, because these ecosystems are very susceptible to fire.
The risk and intensity of damage are vary depending on the size of the area, age, intensity of the fire and time of year. Fires have been a matter of continuous concern in the dry season, when most of the damage to the ecosystem could be experienced in cities located in the referred area, which were covered by smoke and ash (Medeiros, 2002).

In Brazil, the causes of forest fires in the Cerrado were mostly associated to incorrect use of firefighting equipment: lack of fire lines, climate conditions and lack of fire control equipment. Also, illegal burning is one important cause of these fires. Recent studies have shown that 67% of the burned areas in Brazil (in 2000) were in Cerrado (Tansey et al. 2004).
According to Vicentini (1993) and Silva et al. (2009) the Cerrado has been increasingly occupied and converted into agricultural land. The author affirms that the Conservation Units located in this biome have been constantly impacted by the action of frequent forest fires. Intensive agriculture is one of the factors that contribute to the generation of Conservation Units of small areas, which presents one or more vulnerable characteristics due to the occurrence of fires, as previously mentioned.
Besides releasing carbon dioxide (CO_2) into the atmosphere, burning can release other gases that cause global warming, and high frequency of fire affects the establishment of trees and shrubs (Hoffmann & Moreira, 2002, Krug et al., 2002).

4. Used data

The scanner Thematic Mapper (TM), coupled in Landsat 5, sense data in seven spectral bands simultaneously. Band 6 senses thermal infrared radiation and can only acquire night scenes. The resolution on the ground (spatial) in bands 1-5 and 7 are 30 square meters and in band 6 is 120 square meters.
Bands 1 (blue, 0.45-0.52μm), 2 (green, 0.52-0.60μm) and 3 (red, 0.63-0.69μm) are obtained in the waves lengths of the visible in the electromagnetic spectrum; while the bands 4-7 are collected in infrared region (4 - infrared near, 0.76-0.90μm; 5 – infrared medium, 1.55-1.75μm; 6 – infrared thermal, 10.4-12.5μm; and 7 – infrared medium, 2.08-2.35μm). Additional information on program Landsat can be seen in NASA (2011).
Only bands 3 and 4 were used in the experiments conducted in this paper. Band 2 was only used in the generation of the color composition (Fig. 3). An image was obtained in the quarter ASO (August, September and October) of every studied year, which corresponding to the drought periods. This study comprises the years 1985, 1987, 1989, 1996, 1998, 2000, 2007, 2008 and 2010, in agreement with the readiness of TM data and with the occurrence of the climatic phenomena El-Niño and La-Niña. Fig. 3 shows the UUES in 1989.

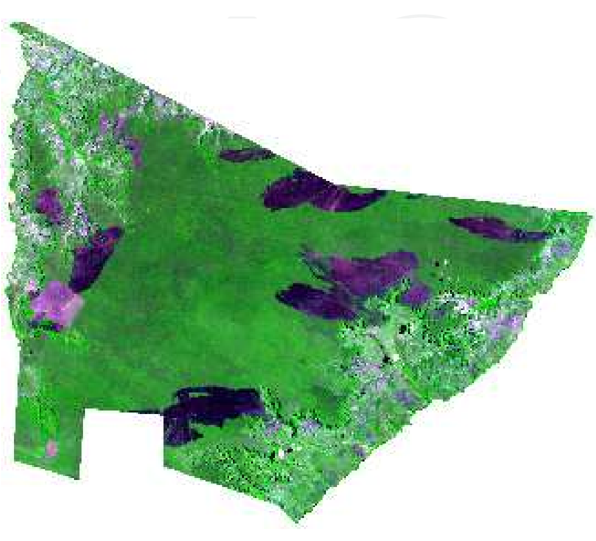


Fig. 3. Image of the UUES area in 1989

Imaging processing is performed using the software MatLabR2007a, Multispec3.2 and Envi4.2.

5. Method

For better understanding, the proposed method is divided into five distinct phases. The first stage concerns data collection and image pre-processing. In the second phase there is NDVI calculation and the isolation of band 4 (near infrared - IR). The creation of routines that detect fires using two test images and that is based on a threshold T is performed in the third phase. The information on the existing biodiversity in the UUES and the pre-processing and data collection steps occur in the fourth phase. Finally, the fifth phase concerns analysis of the results based on the quantification of burned areas and climatic phenomena.

5.1 Obtaining and pre-processing the data

All the nine images were geometrically corrected by means of image registration. The reference (georeferenced) image was also provided by INPE, at no cost, and the control points were collected in this image. Landsat TM images are first corrected by INPE, but with approximate coordinates, which simplifies the record of these scenes. For this reason, a first-degree polynomial model and the interpolator "nearest neighbor", which maintains the original Digital Values DV (or Gray Levels), were used. Since the digital values define the different features in digital images, depending on the intensity of the changes of the digital values, it could be difficult to carry out fire analyses.

5.2 Preparing the NDVI and IR images

The spectral signature of the "burned" feature varies according to the fire status at the moment of image collection. If there is a fire, the digital values in the green (G) and red (R) bands are medium or close; and in the infrared band (IR), the DV are low. Though, when there is no fire, the DV in the IR band is null, spectral characteristics of the ash and coal. In the G band, the DV are low, being however larger than the values found in the R band. In this context, the pixels of the "burned" class can be classified by vegetation indexes, which are based on the difference between the DV of the IR and R bands.
NDVI (Normalized Difference Vegetation Index) – index is selected because of its efficiency in the identification of burned areas. The method is widely recognized in the literature and uses simple calculations. This index is calculated by equation 1

$$NDVI = (IR-R)/(IR+R) \tag{1}$$

The isolation of the IR band (band 4 - TM) is a simple task, which is performed by ensuring the geometrical correction and cut out over the area of interest. There are no alterations in the original digital values in this band. Fig. 4 illustrates the image IR band and the resulting image of the NDVI calculation, both originated from the image shown in Fig. 3.
The simultaneous use of two images (NDVI and IR) is demonstrated in circles and rectangles illustrated in Fig. 4a and 4b. In the IR image (Fig. 4a) the burned area in the circle is not well identified as in the NDVI image. On the other hand, the cultivation area shown in the rectangle can be mistaken with the burned area in the NDVI image, whereas in the area in the IR image it is easily separated. Thus, the two images together provide a more accurate classification.

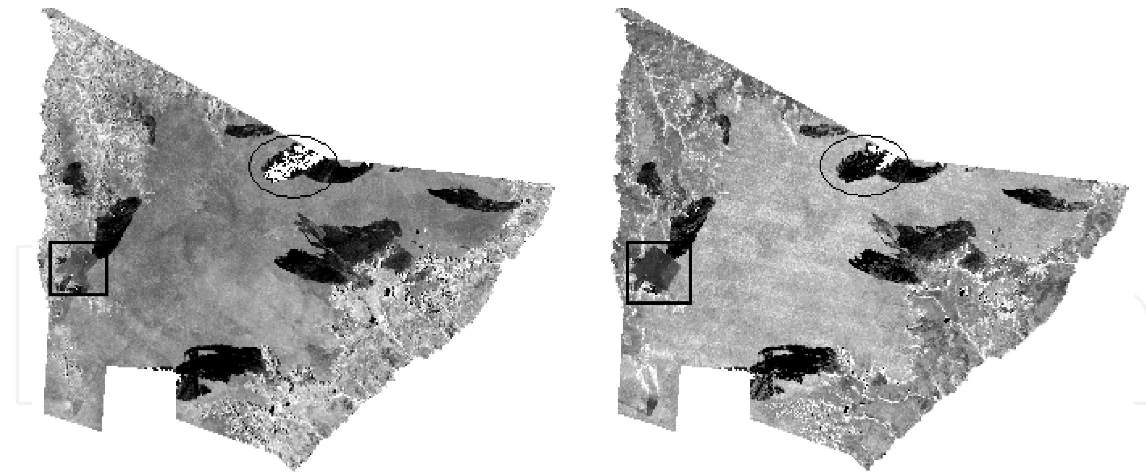


Fig. 4. Near infrared band - IR (a) and NDVI image (b)

5.3 Identification of burned areas in digital images

The areas corresponding to the "burned" features are identified in the IR and NDVI images (Fig. 4a and 4b). Due to the spectral characteristics of this feature (burned), the digital values in the NDVI image are negative and close to value -1. So, a threshold T is empirically established to isolate the burned areas from the other features in the image. All digital values of the NDVI image smaller or equal to T are labeled as belonging to the feature “burned”, and the others (>T) as “unburned”. The same procedure is used in IR imaging, but the magnitude of new threshold is T1.

The resulting images of threshold T and T1 applications are submitted to convolution with the morphological operator “opening”, aiming to eliminate the noise in T and T1 operations. The opening of NDVI or IR images by operator B (structuring element) is obtained by the erosion of these images with B, followed again by dilation of the resulting image by B. The mathematical representation of the morphological operation with the NDVI image is given by equation 2.

$$NDVI \circ B = (NDVI \ominus B) \oplus B \quad (2)$$

The structuring element B can be defined in many ways: linear, circular, rectangular or diagonal. The entire process involved in the identification of burned areas is accomplished by routines developed in MatLab2007a. Finally, the burned areas obtained from the NDVI and IR images are added (arithmetic operation), to fill up spaces that were not visible with the use of other techniques.

5.4 Classification of the Biome in UUES

The classification of vegetation types affected by forest fires within the study area (UUES) is done by *in loco* visits. The present study was conducted by a group of researchers and members of ICMBio (Chico Mendes Institute for Biodiversity Conservation) responsible for monitoring the UUES. The group crossed the UUES, passing through a rural road towards the North and the South, and used also a side access road.

Some central points of the burned areas detected in the digital images are used as reference in the collection of information concerning the type of vegetation in this area. In each point, the geodetic coordinates are recorded and the information of the vegetation physiognomy is collected in the neighborhood within a radius of approximately 200 meters. This information is stored as data points and then interpolated to other points on the area. Additionally, a photographic record is made at each point, e. g. in Fig. 5.

Fig. 5. Photographic record of local vegetation

Information on the vegetation is superimposed on burned areas, which are generated from the NDVI and IR, to measure and record biodiversity losses. The overlapping or crossing of this information is performed using routines developed in MatLab2007a.

5.5 Behavior of climatic phenomena

Finally, the results of all the experiments are assessed in relation to the climatic phenomena El-Niño and La-Niña, in order to determine whether or not these phenomena have influence on burnings. This analysis is done by checking the size of the burned area and the behavior of weather phenomena in the analyzed year. According to CPC (2010), the occurrence of the climatic phenomenon can be represented by indexes.

The quarterly values of the indices corresponding to the occurrence of El Niño and La Niña are graphically plotted (Fig. 6), in order to describe the behavior of these phenomena over time. The period represented on the graph varies between the years 1982 and 2010. Each year is punctuated by twelve quarters that overlap each other, for example, JFM (January, February and March) is the first quarter; the second is FMA (February, March and April);

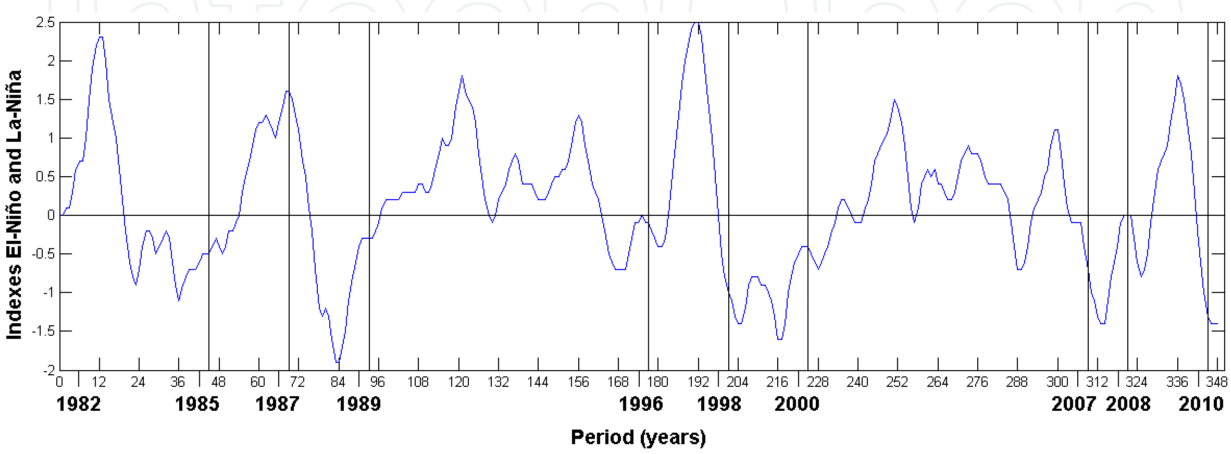


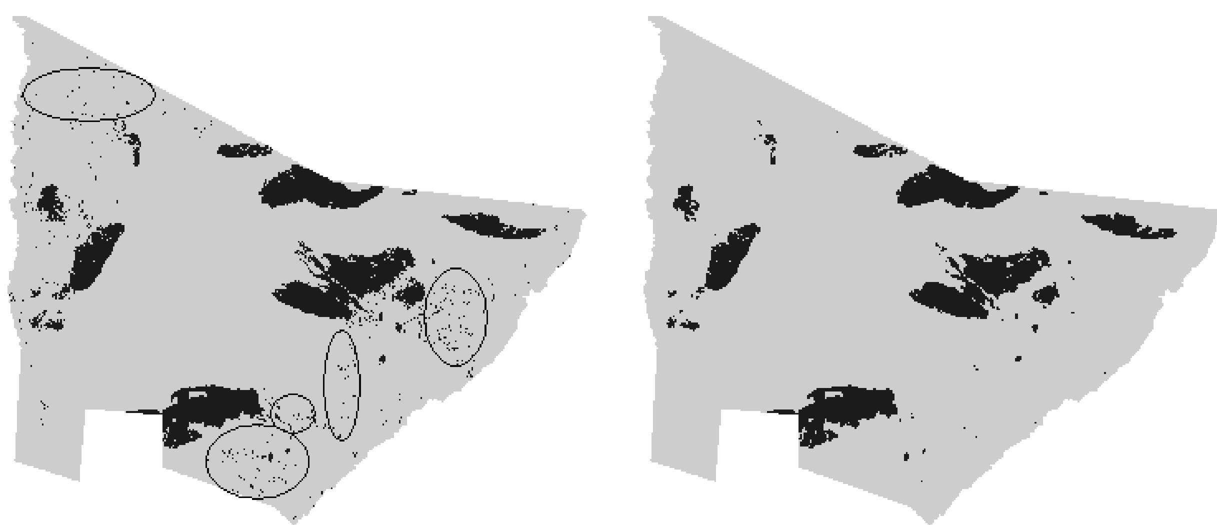
Fig. 6. El Niño and La Niña based in limit of ±0.5 °C for the Oceanic Niño Index

the third is MAM (March, April and May), and so on. This index is based on the limit of ±0.5 °C for the anomalous temperature at the sea surface (SST) in the Niño 3.4 region (5°N to 5°S latitude and 120°W 170°W longitude). Positive values of this index evince the occurrence of El Niño and negative values indicate the occurrence of La Niña.

In Fig. 6 the x-axis shows the year represented by the 12 quarters. Thus, year 1982 is represented by number 12, 1983 is represented by number 24, 1984 by 36, and so on. The assessed years in the present study are shown in vertical lines in Fig. 6.

6. Results and discussion

The constants used in this study are presented below. In the image registration procedure, the largest root mean square error (RMS) measured was 0.48 pixel. The values used for thresholds T and T1 in the identification of burned areas were 0.4 and 80, respectively. The structuring element B used in "opening" operation is the disc of radius 5. Essentially, opening removes small objects/noises (<5 pixels). The side effect is the elimination of the edges to round the objects. Although the burned areas may be partially (large areas) or totally (small areas) eliminated by the opening, this technique is very effective to eliminate noise. In Fig. 7 is shown an example in image IR-1989.



(a) (b)

Fig. 7. Points eliminated by the opening operation.

Several points detected as burning alone (Fig. 7a) were removed by opening operation (Fig. 7b). The circles exposed in Fig. 7a show concentration of these points (noise), what were eliminated with the application of that technique morphology.

The burned areas identified in the Landsat 5 TM images, concerning the nine years analyzed, can be seen in Fig. 8.

Visually, it can be inferred that in 1985 there were few fires, which were more frequent across the borders of the UUES area. One possible explanation is that some areas of the UUES are inhabited, and burning is used for the practice of subsistence farming. In the following years (1987, 1989 and 1996) an abrupt expansion of the burned areas was observed, although with a small decline between 1996 and 1998. According to members of ICMBio, this increase was due to the advent of intensive agriculture and the absence of firefighting groups close to UUES in that period. In the 2000s, the fire brigades fought the fires in the area. Besides, climatic factors must be taken into consideration. However, they shall be discussed later.

For a quantitative analysis, all the areas were measured in square kilometers and represented graphically, as shown in Fig. 9.

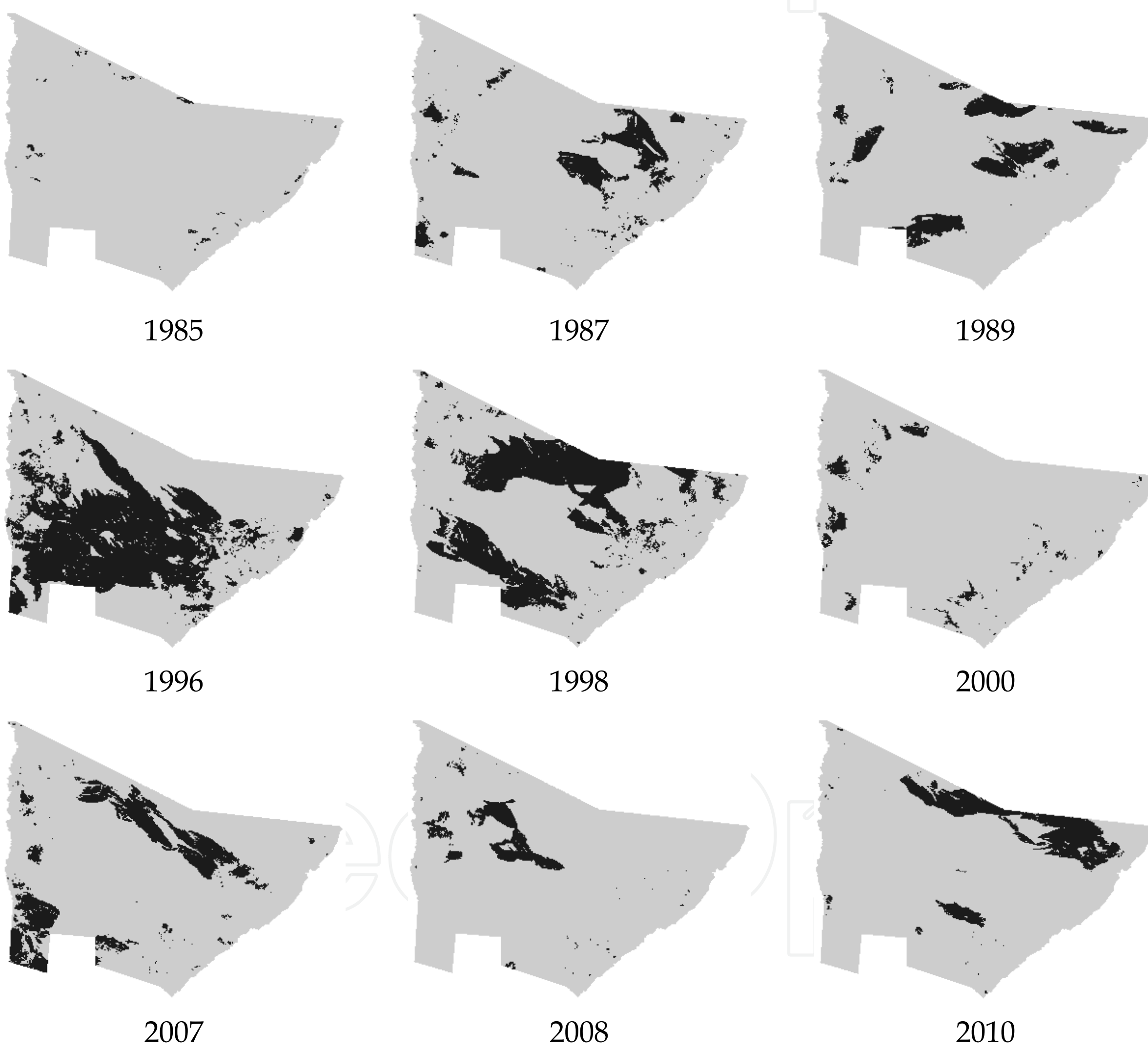


Fig. 8. Forest fires happened in the analyzed years

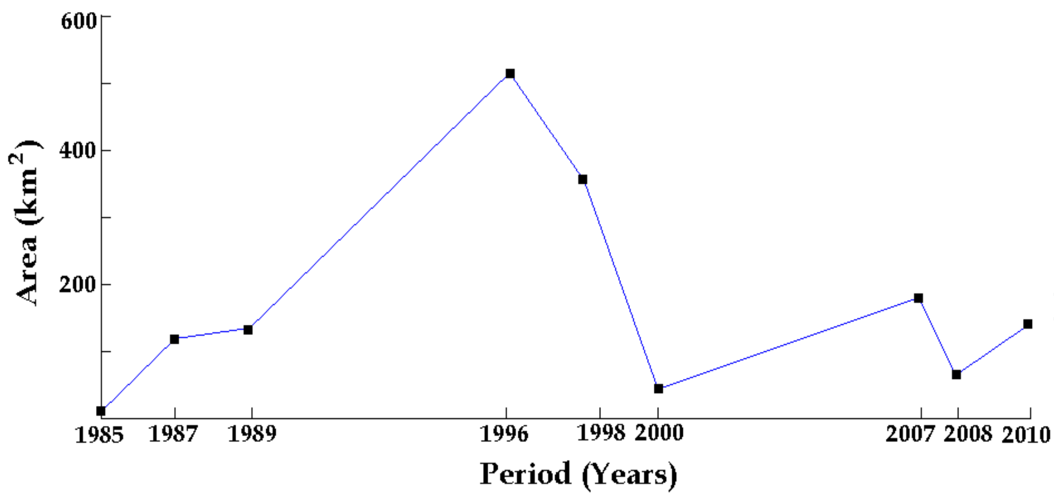


Fig. 9. Graphic representation of the measures of the burned areas

The peak that occurred in 1996 shows that 37.40% of the UUES area was reached by fire, which is more than the index measured (37.18%) for the sum of the burned areas in all the other years except for 1998 and 2007. The areas least affected by fires in 1985 and 2000 were 8.59 and 43.33 km^2, respectively. Fig. 10 shows that 67.25% (black area) of the UUES area was reached by fire in at least one of the years analyzed.

Fig. 10. Total area affected by fire in years analyzed.

In loco observation showed that most burned areas correspond to the physiognomies of *cerrado sensu stricto*, especially in upland areas (plateaux). Only one of the study areas was classified as *campo cerrado*. The areas located in the bottom (valley), which were also affected by fires corresponded to *cerrado stricto sensu anthropic*. According to Medeiros & Cunha

(2006), the dominant vegetation in the Ecological Station of Uruçui-Una is really the *cerrado strict sensu*.

It is known that depending on the intensity and frequency, forest fires may cause severe damage to the vegetation. However, during the *in loco* visit it was found that the vegetation in some areas was at an advanced stage of regeneration, indicating resilience. Fire is an important factor in maintaining biodiversity, since while some species are affected by fires, others may be benefited in the process of germination and dormancy break of seeds. Thus, the frequency of fires in UUES may be the cause of the predominance of the two existing physiognomic forms. If the germination of tree species is prevented from occurring because of periodic fires, there is a decrease in the density of trees in the region, which leads to a change in the *cerrado sensu amplo* forest landscape, with a larger concentration of trees.

Analysis of fire recurrence (Fig. 11) was carried out in areas adjacent to the checkpoint that characterized the physiognomic form *campo cerrado*. In this region, biodiversity loss is apparent (Fig. 5). Considering the combined damage of fauna and flora, this loss is still more serious.

The area of recurrence of fires presented in Fig. 11 measures 9.53 km^2. The measure of this area was determined in the intersection of the burned areas for the years 1978, 1989, 1996 and 1998. Since the burned areas coincided in only two years, a considerable variation occurs depending on the pairs of years analyzed. Table 1 shows this variation.

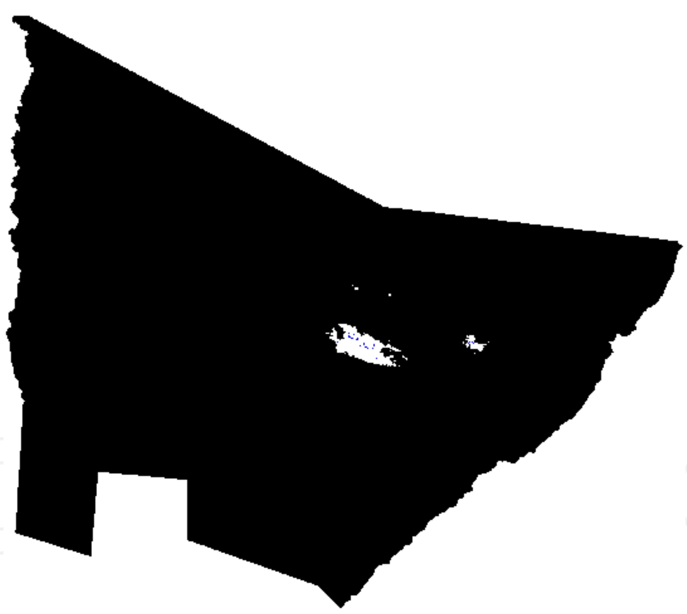


Fig. 11. Areas of recurrence of fires in period 1978-1998

All the indexes for the year 1985 are low due to the small extent and sparse spatial distribution of the burned areas. 1996, on the contrary, as the year with the largest area of intersection with another year, especially the 1996-1998 pair, which had an area of intersection of 135.25 km2. The intersection of burned areas in 1996 was due to the spatial extension and homogeneity of the area.

Analysis of the graphs of Figs. 6 and 9 shows that the La-Niña climate phenomenon has started two years before 1985. This phenomenon may also have contributed to the reduced number of fires that occurred in that year. The El-Niño climatic phenomenon occurred in the 1985-1987 period. Consequently, the graph of Fig. 9 shows an increase in the burned areas. Between 1987 and 1989 a transition from El-Niño to La-Niña was seen, with La Niña prevailing most of the time. The total amount of burned areas remained almost constant, with a slightly positive trend. Soon after, in a longer period (1989 to 1996) a predominance of El-Niño was observed, which corresponds to the period when the largest areas were destroyed by fires, being consistent with the heating caused by the phenomenon. Although smaller than the previous period, the size of the burned areas between 1996 and 1998 was relatively large, in agreement with the peak of El-Niño in Fig. 6. Cooling happened in the subsequent period (1998-2000) coinciding with the abrupt decrease in the total burned area. Despite a weak intensity the El-Niño phenomenon prevailed in the 2000–2007 interval. Hence, the curve of the area showed again a positive trend. In the last two intervals of time analyzed the consistency of reduction of the burned area in the period of La-Niña (2007-2008) was maintained and there was an increase in the El-Niño phenomenon (2008-2010).

Years	**1987**	**1989**	**1996**	**1998**	**2000**	**2007**	**2008**	**2010**
1985	0.93	1.33	3.55	1.82	0.35	0.89	0.22	1.57
1987		25.12	54.41	28.15	7.07	26.85	3.18	18.57
1989			66.10	78.02	4.27	31.68	4.75	24.79
1996				135.25	11.19	75.73	36.07	15.85
1998					6.40	77.25	20.06	57.14
2000						4.46	2.48	2.54
2007							0.15	21.92
2008								0.23

Table 1. Burned areas (km^2) coincide with each other

It is assumed that there is increased incidence of fires during the El-Niño phenomenon and that the opposite occurs during La-Niña. During the El-Niño periods there is an increase in temperature, which causes the vegetation to dry, favoring the fast propagation of the fire. On the other hand, during the La-Niña phenomenon, cooling is more frequent, which increases the intensity of rains, helping eliminate the fires. Thus, the two graphs (Fig. 6 and Fig. 9) show the existence of this correlation between the climatic phenomena and the intensity of burned areas in UUES.

7. Conclusion

The findings of the present study allow inferring the intensity, distribution form, location and cause of the fires that took place in the Uruçuí-Una Ecological Station (UUES), as well as the biodiversity loss provoked by these fires. Additionally, it is possible to infer the influence of the climatic phenomena El-Niño and La-Niña on the occurrence of fires.

In agreement with the results obtained, the Landsat 5 TM images were found to be useful in the analyses of fires in CUs, especially due to the collection frequency and quality spectral/spatial of the data.

The burned locations were correctly defined in the proposed method. They were located so much the burned areas individualized by year, as the total area reached by fire in the analyzed period. Additionally, all the areas were measured facilitating a more detailed analysis concerning the intensity of the fire.

The burning frequency was also accurately measured, indicating the recurrence of fire among pairs of years and in the most affected years. The study of the frequency of fires made it possible to identify the most critical areas, elaborate a strategy to support fire fighting, e. g., the creation of rural roads or accesses to these areas to facilitate the movement of the fire brigades.

The variation of the type of vegetation (biodiversity loss) was analyzed based on the occurrence of fire. It was noticed that in areas of high fire frequency the physiognomy of *cerrado sensu stricto* vegetation was changed into *campo cerrado* because of the damage caused to some species by the fires.

The products (burned map and descriptive information) generated in this research are important tools for governmental authorities in Brazilian Conservation Units (e. g. in ICMBio), particularly to promote innovation of public politics in the prevention and control management of fires within the ES (Ecological Stations). Besides, they provide insights for future research on environmental preservation and continuous monitoring of protected areas.

8. Acknowledgments

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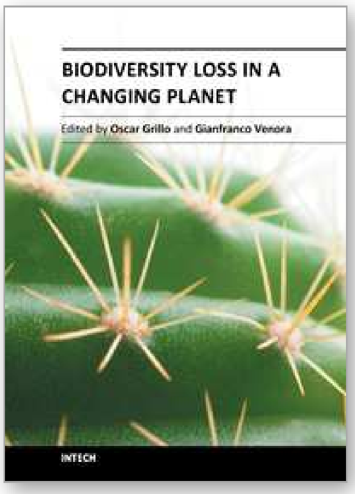

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Every ecosystem is a complex organization of carefully mixed life forms; a dynamic and particularly sensible system. Consequently, their progressive decline may accelerate climate change and vice versa, influencing flora and fauna composition and distribution, resulting in the loss of biodiversity. Climate changes effects are the principal topics of this volume. Written by internationally renowned contributors, Biodiversity loss in a changing planet offers attractive study cases focused on biodiversity evaluations and provisions in several different ecosystems, analysing the current life condition of many life forms, and covering very different biogeographic zones of the planet.