EVOLUTION OF DEFORESTATION IN THE BRAZILIAN PANTANAL AND SURROUNDINGS IN THE TIMEFRAME 1976 - 2008

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Abstract

Maps elaborated from five different periods were recovered and inserted within a single GIS. Considering these maps, the evolution of deforestation in the Pantanal and its surroundings in Brazil was analyzed for the last 32 years and scenarios were described for the timeframe 2010-2050. The results for the different BAP (Floodplain and Plateau), BAP (Mato Grosso and Mato Grosso do Sul States), BAP (Biomes: Pantanal, *Cerrado* and Amazon). Until 2008, the deforestation on the Pantanal floodplain affected 12,14% of its area, while on the Plateau 58,90% were concerned. The actual deforestation percentages indicate that, if no effective control actions are taken, the natural vegetation from this region could be eliminated till 2050. As an instrument for the effective deforestation control, we suggest the implantation of a deforestation monitoring system on the river basin of the Upper Paraguay, based on information technology.

Key words: Geo-Technology. Average rate of geometric growth. Deforestation scenarios. Biomes. Upper Paraguay river basin.

Resumo

Evolução do desmatamento no pantanal brasileiro e entorno de 1976 a 2008

Mapas elaborados em cinco épocas distintas foram recuperados e inseridos num único Sistema de Informação Geográfica. Por meio desses mapeamentos foi analisada a evolução do desmatamento do Pantanal e seu entorno no Brasil nos últimos 32 anos e traçados cenários para o período de 2010 a 2050. São apresentados resultados para cada uma das épocas em diversas subdivisões BAP (planície e planalto), BAP (MT e MS), BAP (Biomas: Pantanal, Cerrado e Amazônia). Até 2008, o desmatamento na planície do Pantanal atingiu 12,14% de sua área, enquanto que no planalto havia atingido 58,90%. Os percentuais atuais apontam, que se não houver ações de controle efetivas, a vegetação natural da região poderá ser suprimida até o ano de 2050. Como uma das formas de efetividade no controle do desmatamento, sugere-se a implantação de um sistema de monitoramento do desmatamento na bacia hidrográfica do Alto Paraguai baseado na tecnologia da informação.

Palavras-chave: Geotecnologia. Taxa média de crescimento geométrico. Cenários de desmatamento. Biomas. Bacia hidrográfica do alto Paraguai.

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INTRODUCTION

The deforestation issue permeates discussions worldwide (ANGELSEN; KAIMOWITZ, 2001), involving managers, scientists, environmentalists and developers, each one with his/her interests and arguments. Nevertheless there is an almost unanimous certainty: the indiscriminate and without control deforestation is prejudicial for the planet Earth, and it is responsible for changes and climate impacts. It causes harmful effects to the planet, both on global and regional or local scale. Actions related to deforestation are frequently associated to the emission of greenhouse gases, specially on the emission of CO_2 which, according to Cerri et al. (2009), is emitted above the global average by Brazil, contributing to climatic changes that affect directly the equilibrium of the environment.

There are many impacts of human activities on natural resources, and among them the transformation of the natural landscape by deforestation, can be considered as one of the most significant ones, because it fragments ecosystems and substitutes native vegetation to livestock with planted pasture, to plantations of grains and fruits, to reforestation and to buildings. Such impacts over the biodiversity are appointed out by Vieira et al. (2008) in his study from the Amazon region.

The natural vegetation cover is an important indicator of the environmental conditions from a region. It propitiates soil protection, reducing sediment transport and siltation of water bodies, besides being the habitat for wild animals contributing so for the maintenance of biodiversity. According to Alho (2008) the loss or alteration of habitats due to conversion of natural vegetation by human occupation, is a real threat with prejudice for the biodiversity of the Pantanal, which is expressive in superior plants (3,400 species – 1,863 phanerogams); fishes (400 species – 263 in the Pantanal); reptiles (179 species, 85 in the Pantanal and 94 on the Plateau); amphibians (80 species, 35 occurring in the Pantanal and 45 on the Plateau); Birds (661 species, 444 in the flooded part of the Pantanal); mammals (195 species distributed in the Pantanal and in the surrounding *Cerrado*) (MMA, 2006).

In the Upper Paraguay river basin (BAP), where the Pantanal is inserted, the suppression of native vegetation is extremely important, because the environmental impacts (siltation of rivers, inundation, loss of habitats) which occur on its floodplain, are caused by transportation of sediments originated from the Plateau adjacent to the basin (ABDON, 2004: ABDON et al. 2005) caused by deforestation. It is emphasized that the production system on the adjacent Plateau is based on livestock over planted pasture and on grain (soybeans, maize, cotton) and so the pressure to deforestation is higher on the Plateau than on the plain, where the production system is based on livestock (breeding) on natural pasture (SILVA et al. 2003; SILVA et al. 2005).

To know where deforestation is occurring, which is the speed of its increase in time, the identification of possible regions (biomes, States, Plateau, Floodplain) where the deforestation pressure is higher, are helpful information for managers to take decisions and transform them in public policies, for the benefit of society.

The Pantanal region and its river basin at the Brazilian part of it has a reasonable set of mappings on deforestation. At the Upper Paraguay (BAP) river basin located at both States (Mato Grosso and Mato Grosso do Sul), the deforestation until 1994, according to Silva & Abdon (1997) totalized over 110,000 km^2. The largest part of this deforestation is localized on the Plateau (93.7%) and the remaining (6.3%) on the Pantanal. Within the Pantanal 5% was deforested till 1994, while at the Plateau this figure reaches 46.2%.

Besides this deforestation mapping at BAP till 1994, in Silva et al. (2001a and 2001b) there are deforestation mappings at BAP, scale 1:250,000, till 1976 and 1984. At Silva et al. (1998) one verifies the deforestation mapping in the Pantanal floodplain till 1991; Padovani et al. (2004) shows the deforestation of this area till 2000 and Abdon et al. (2007) presents the deforestation of the Pantanal biome till 2002. Considering the studies performed by the

Ministry for Environment (MMA, 2009), Monitoriamento (2009) and MMA (2010), it was possible to elaborate a continuous deforestation mapping for the entire basin till 2008.

We emphasize that presently the Ministry for Environment has a monitoring program from the vegetation cover of the Brazilian Biomes, but this program does not consider data earlier than 2002, precluding the construction of scenarios. In this frame it would be important that governmental agencies implant a monitoring system for the Upper Paraguay river basin, which considers also earlier data.

OBJECTIVES

a) To analyze the deforestation at the Brazilian Upper Paraguay river basin in the timeframe 1976-2008, considering the following sub-divisions: Plateau, Floodplain, Mato Grosso and Mato Grosso do Sul States.

b) To analyze the deforestation at the Brazilian Upper Paraguay river basin in the timeframe 1976-2008, considering the existing biomes: Pantanal, *Cerrado* and Amazon region.

c) To analyze the deforestation within the Brazilian Pantanal (Floodplain and Biome) in the timeframe 1976-2008.

d) To elaborate deforestation scenarios at the Brazilian Upper Paraguay river basin for the next 40 years.

MATERIALS AND METHODS

Area under study

In this paper we focus on areas whose borders define the Brazilian Upper Paraguay river basin and the biomes composing it, specially the Pantanal floodplain and the Pantanal biome in Brazil.

A) The Upper Paraguay river basin in Brazil – according to Silva & Abdon (1998) this area is located in the center of South America, occupying sections in Brazil, Paraguay and Bolivia. In the Brazilian territory it has an area of 361,666 km^2 , between latitudes S 15º 30' to S 22º 30' and longitudes W 54º 45' to W 58º 30', bordering with Bolivia and Paraguay. The Brazilian portion occupies partial areas of States Mato Grosso and Mato Grosso do Sul. Referring to the relief, two distinct areas can be observed: the Pantanal floodplain and the adjacent Plateau.

B) Existing biomes in the Upper Paraguay river basin - the Brazilian portion of this basin, according to IBGE (2004) has partial areas of the Cerrado and Amazon biomes, and totally the Pantanal biome.

C) The Pantanal floodplain and biome in Brazil – the floodplain of Pantanal occupies an area of 138,183 km^2 , (SILVA; ABDON, 1998) and the Pantanal biome 150,335 km^2 , according to IBGE (2004).

After conversion to the Albers projection system and necessary adjustments, those BAP and Pantanal floodplain areas (SILVA; ABDON, 1998) and of the Pantanal biome (IBGE, 2004) were recalculated to 361,782 km^2 , 138,424 km^2 and 151,072 km^2 respectively. Therefore for the calculation of percentage these values were used.

In order to improve the different sub-divisions of BAP, figure 1 was elaborated, where the following sub-divisions can be observed: division by States (Mato Grosso and Mato Grosso do Sul), Biomes (Pantanal, *Cerrado* and Amazon) and Plateau and Floodplain.

These delimitations are helpful for the reader to situate himself when analyzing the occurrence of deforestation in the region under study. Special attention must be given to the contours of Biome and of the Pantanal floodplain because they have different borders at Northwest, where the Biome includes a large flat area from the Pantanal depression to the west of the city of Cáceres and also at the western border where the adjacent mountains are included. Due to that, those deforested areas in the Biome present always higher values than those from the floodplain, which can lead to erroneous decisions related to planning and definition of public policies.

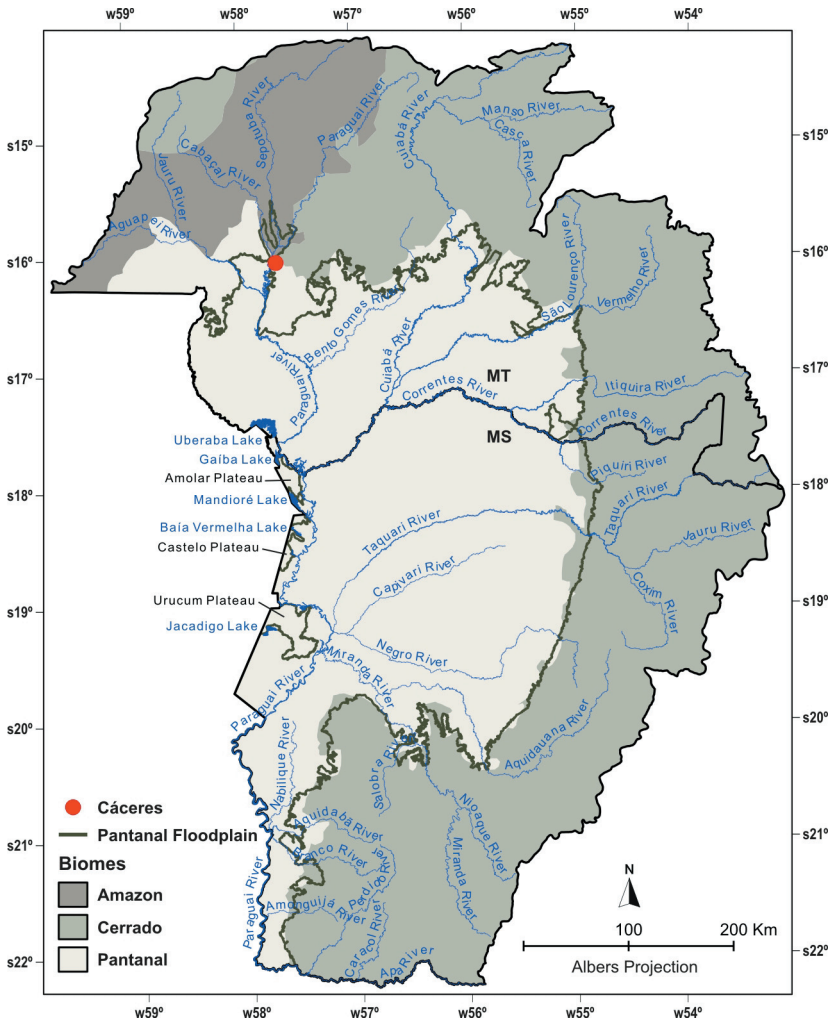

Figure 1 – Upper Paraguay river basin and its different sub-divisions

Methodology

The following accumulated deforestation mappings for the BAP were recovered until the years: 1976 (SILVA et al., 2001a), 1984 (SILVA et al., 2001b), 1994 (SILVA et al.,1997), 2002 (SILVA et al., 2007; ABDON, 2007; FERRARI et al.,2009, MONITORAMENTO, 2009) and 2008 (MMA, 2009; MMA, 2010; MONITORAMENTO, 2009). The first three mappings mentioned (1976, 1984 and 1994) were made by visual interpretation in analogical images at scale 1:250,000, using data from LANDSAT 5 satellite, sensor TM5. The mappings for the years 2002 ands 2008 were executed also by visual interpretation and with satellite images, but using digital images.

The deforestation maps of 1976, 1984 and 1994 were elaborated from 34 charts at 1:250,000 which compose the BAP. These maps were articulated and adjusted using the SPRING GIS (CÂMARA et al., 1996).

The deforestation map from 2002 was elaborated as follows: a) the Pantanal Biome was worked from the vegetation maps of the Pantanal (SILVA et al., 2007; ABDON et al., 2007; FERRARI et al. 2009) which was already articulated and a mosaic made; b) the biome *Cerrado* in the State Mato Grosso do Sul was recovered from the paper authored by Silva et al., (2010), whose mosaic was elaborated from using charts from Mapeamento (2007); c) The Cerrado biome, in the Mato Grosso State, was elaborated by an articulation, adjustment and junction of charts at 1:250,000, recovered from Mapeamento (2007); d) the biome Amazon was elaborated by subtracting deforested areas till 2008 from those deforested in the timeframe 2002-2008, originated from Monitoramento (2009) after the due cutting of Amazon biome area included at BAP. For cutting and junction of deforested areas the SIG Spring and ArcGIS were used.

The deforestation map of 2008 was elaborated as follows: a) the Pantanal Biome was used without change from the MMA (2010) study; b) the *Cerrado* Biome was elaborated from the mosaic of the *Cerrado* Biome (MMA, 2009) and the inherent part to BAP was cut; c) the Amazon Biome was cut from the mapping made by Monitoramento (2009).

After the due conversions, cuts, adjustments and mosaicing, the maps of five dates were converted to a single GIS – SPRING, at Albers projection, Datum SAD69, where the calculations of the deforested areas for the Pantanal floodplain and the adjacent plateau were done, totaling in each State (Mato Grosso and Mato Grosso do Sul); total Biomes (Pantanal, Cerrado, Amazon) and BAP for each State. The crossed tab function was used, with 60 m resolution for intersection and calculation of areas.

It must be highlighted that the older maps (from 1976, 1984 and 1994) of BAP and from the floodplain were constructed on analogical form and digitized using a light table. They were recovered in form of 1:250,000 charts (1º x 1.5º) and UTM projection. When the junction procedure started, some inclusions and exclusions of data in the border of the charts were verified, which were eliminated and adjusted to the new base, created automatically. Such imperfections can be attributed to discrepancies of observed areas. Referring to the map of biomes received, it was at scale 1:5,000,000, at poly-conic projection, because it is a map covering the entire national territory. There was no need to do adjustments but, after cutting the Pantanal biome, the calculated area was different from that one published by IBGE (2004).

For the analysis of the evolution of deforestation at BAP and its different sub-divisions, graphs were elaborated with the accumulated values of deforested areas until each period analyzed. So the values for 1976, 1984, 1994, 2002 and 2008 refer to the area mapped and quantified off all deforestation till each date.

From each period analyzed the average yearly increment of deforestation was obtained, using the average geometric growth rate, obtained by the following expression:

TMGC = (((D(t+n))/D(t))^(1/n))-1,

Where:

n is the number of years of the interval for the calculus of the rate;
D(t+n) is the deforested area calculated at a later date (or at the final time);
D(t) is the deforested area calculated at a later date (or at the final time), in km² for this case;
(1/n) is the inverse number of years from the interval for the calculation of the rate.

RESULTS AND DISCUSSION

Table 1 presents the accumulated deforestation values of five dates (1976, 1984, 1994, 2002 and 2008) for the period analyzed at BAP and its sub-divisions. Such data were used for the calculation of deforestation percentage per territory, the elaboration of graphs and average geometric growth rates, which subsidize the discussion to follow.

Table 1 - Area (km²) of accumulated deforestation at BAP till 1976, 1984, 1994, 2002 and 2008

Physiographic Delimitation	Physical area	Deforested area (km²) till				
		1976	1984	1994	2002	2008
BAP (floodplain/plateau						
Floodplain	138,423.7	634.9	2,880.2	7,021.4	11,818.7	16,798.1
Plateau	223,358.7	10,783.5	53,509.3	104,948.7	112,729.1	131.566.8
BAP total	361,782.4	11,418.4	56,389.5	111,970.1	124,547.8	148,364.9
BAP (States)						
Mato Grosso						
Floodplain	49,285,0	244,2	882,1	2,342,6	3,495,8	5,135,7
Plateau	124,786.1	6,270.2	28,687.8	55,258.0	57,372.8	68,175.4
Pantanal Biome	60,996.8	358.2	2,618.9	6,890.9	9,126.0	11,474.9
Cerrado Biome	82,058.5	2,694.3	15,783.3	33,464.9	32,154.4	41,138.9
Amazon Biome	31,015.7	3,462.0	11,167.7	17,244.7	19,588.3	20,697.3
Total BAP in MT	174,071.1	6,514.4	29,569.9	57,600.6	60,868.7	73,311.1
Mato Grosso do Sul						
Floodplain	89,138.7	390.7	1998.1	4,678.8	8322.9	11,662.5
Plateau	98,572.6	4,513.3	24,821.6	49,690.8	55,356.3	63,391.4
Pantanal Biome	90,075.4	613.1	2379.0	4,919.4	8315.2	11,484.5
Cerrado Biome	97,635.9	4,290.9	24,440.6	49,450.1	55,363.9	63,569.4
Amazon Biome	0,0	0,0	0,0	0,0	0,0	0,0
Total BAP in MS	187,711.3	4,904.0	26,819.6	54,369.5	63,679.2	75,053.9
BAP (Biomes)						
Pantanal	151,072.2	971.3	4,998.0	11,810.3	17,441.2	22,959.4
Cerrado	179,694.3	6,985.2	40,223.8	82,915.1	87,518.3	104,708.3
Amazon	31,015.7	3,462.0	11,167.7	17,244.7	19,588.3	20,697.3
Total BAP	361,782.2	11,418.4	56,389.5	111,970.1	124,547.8	148,365.0

Deforestation at the Upper Paraguay river basin (BAP) – Pantanal floodplain, Plateau and States

At figures 2, 3, 4 and 5 there are graphs with deforested areas in absolute and relative values at BAP from the timeframe 1976 to 2008 in different cuttings, and there are always growing values of deforestation in the region. Information on the floodplain, plateau and BAP are found on figure 2; information about the States which compose the BAP are at figure 3 and data on each of the States composing BAP are found on figures 4 and 5.

At figure 2 one observes that deforestation at the Pantanal floodplain is low if compared to the deforestation occurring on the plateau. Plans and governmental incentives, roads, closeness and expansion of cities, the division of States (Mato Grosso [MT] and Mato Grosso do Sul [MS]) executed in 1979, a good soil and adequate relief as well as mechanization of agriculture, they all contributed strongly for the suppression of the natural vegetation and installation of livestock. Some of the factors mentioned, related to the deforestation at BAP, where the Pantanal biome is located, were also observed in the Amazon biome, whose deforestation advancement is related to development policies in the region, such as land speculation along the roads, growth of cities and the dramatic increase of livestock, timber exploration and subsistence agriculture and more recently the mechanized agriculture, specially soybeans and cotton (FEARNSIDE, 2003; ALENCAR et al. 2004; LAURANCE et al. 2004).

In spite of the low deforestation activities in the Pantanal, the curve presented at figure 2, suggests an exponential behavior, different from the deforestation on the plateau which presented a low fall in the curve during 1984 and 2002. It is noteworthy that the exponential behavior in the deforestation evolution will lead to the exhaustion of the natural vegetation resources if no actions are started to inhibit such growth. This fact will initiate a series of negative implications, mentioned already by Hass (2002) and among them the fact that the excessive reduction of areas with native vegetation could cause the extinction of bird species, because they don't survive in small fragments.

In relative terms (calculated by data from table 1) until 2008, the Pantanal floodplain had 12.14% of its area deforested, while at the plateau this figure reached 58.9%. This percentage of deforestation from the plateau area causes preoccupation, since probably the natural area to be suppressed in the plateau adjacent to the Pantanal is close to its limits, requiring more efficient and stringent control actions. One must take into account that the deforestation in the Cerrado areas, where the headwaters of rivers are located, caused erosion and siltation of rivers, changing the water flows and hydrologic regimen in the Pantanal, with negative consequences for the regional biodiversity (HARRIS et al., 2006). According to these authors, the hydrologic processes, modified due to the removal of the vegetation cover change the flood and drought cycles (inundation pulse), largely responsible for all the biological richness of the Pantanal region.

In the BAP analysis, the deforestation advanced from 11,418 km^2 in 1976 to 148,365 km^2 in 2008 (Table 1), with a 13 times increment. While the deforested area in the basin represented 3.2% in 1976, it went up to 41.0% in 2008.

In the period between 1976 and 2008 (table 1) one observes that in the two first periods which comprehend 1976 to 1994, 71.6% of all deforestation in the plateau occurred, while for the floodplain the largest deforestation occurrence (58.2%) was verified in the two last periods, comprehending from 1994 to 2008.

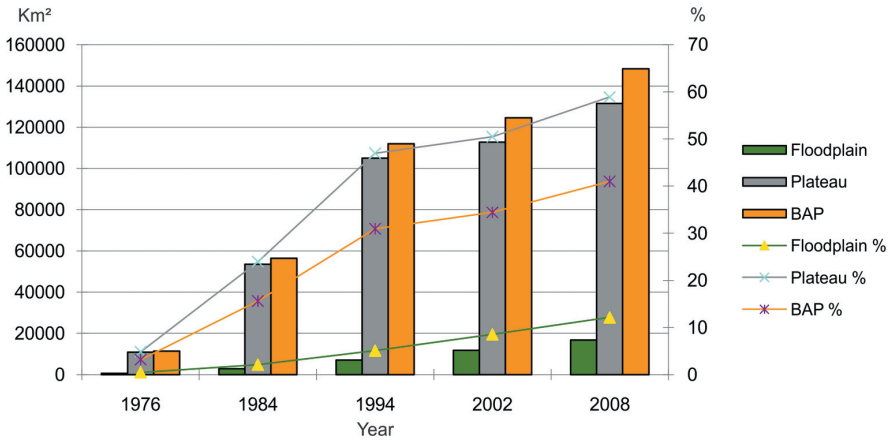

Figure 2 – Accumulated deforested area in the Brazilian BAP in the period from 1976 to 2008

The analysis of the evolution from the deforestation in the State portions of BAP components can be obtained from figure 3 and table 1. Differently when one compares the plateau and the floodplain of the Pantanal, the deforested areas in Mato Grosso and Mato Grosso do Sul States at BAP had a similar behavior during the 32 years analyzed and the deforestation in Mato Grosso State was slightly higher than at the southern State. Nevertheless, from the five dates with accounted deforestation, only in 2002 the difference among both States was 4.13%, falling to 2.14% in 2008. In absolute terms (Table 1) till 2008, BAP in Mato Grosso lost 75,054 km² of its original vegetation cover, while BAP in Mato Grosso do Sul lost 73,311 km² equivalent to the loss of respectively 42.12% and 39.98% from its territory.

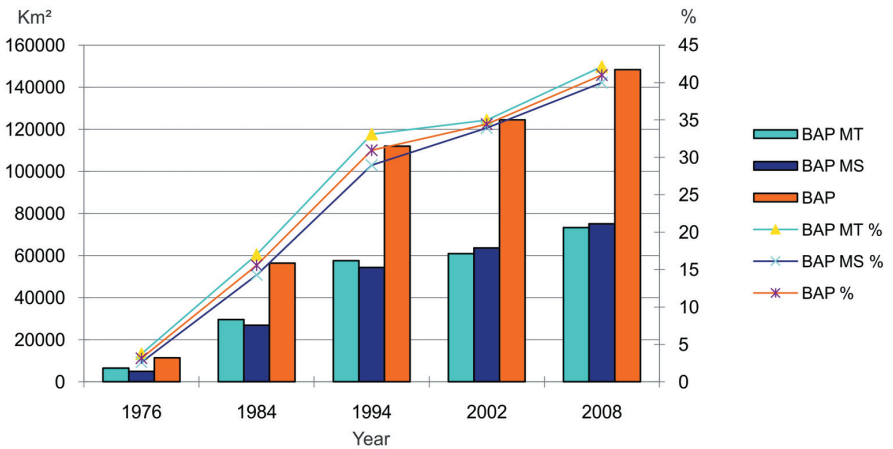

Figure 3 – Accumulated deforested area in the States of Brazilian BAP in the period from 1976 to 2008

At figures 4 and 5 one observes the evolution of deforestation in the territory portions referring to the plateau, Pantanal floodplain and BAP at each one of the States. Comparing these two figures with figures 2 and 3 one verifies that the behavior of the deforestation evolution on the plateau of BAP (Figure 2) is similar to the evolution of deforestation at BAP portions from each State (Figure 3), in both the plateaus of Mato Grosso State (Figure 4) and Mato Grosso do Sul (Figure 5). On the other hand, the behavior of deforestation in the Pantanal (Figure 2) is not similar to the evolution of the deforestation in the BAP, but it is similar to the evolution occurring in the floodplain from each of the two States (Figures 4 and 5).

This finding is quite obvious, since the deforestation on the plateau defines the behavior of the evolution of deforestation at BAP, because of the 148,365 km^2 (Table 1) deforested in PAB till 2008, 88.7% occurred in the plateau.

Analyzing the deforestation occurred till 2008 on the plateau of BAP for each State, one verifies that proportionally the area located in Mato Grosso do Sul is approximately 10% more deforested than the equivalent one in Mato Grosso State. On the plateau of Mato Grosso do Sul State 64.3% were deforested, against 54.3% of the plateau in Mato Grosso State.

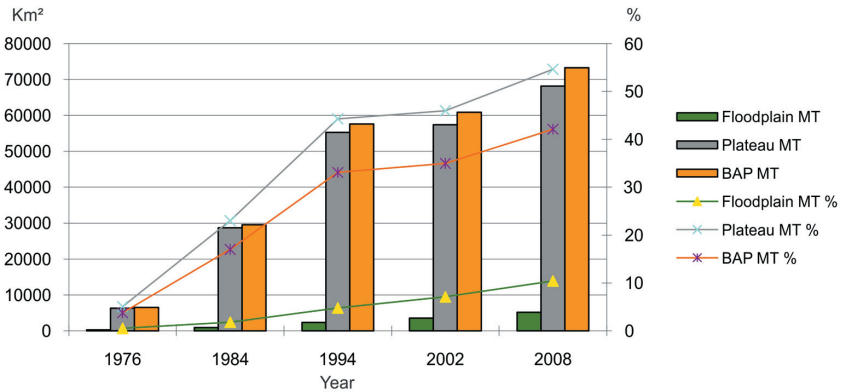

Figure 4 – Accumulated deforested area in the State Mato Grosso localized at BAP in the period from 1976 to 2008

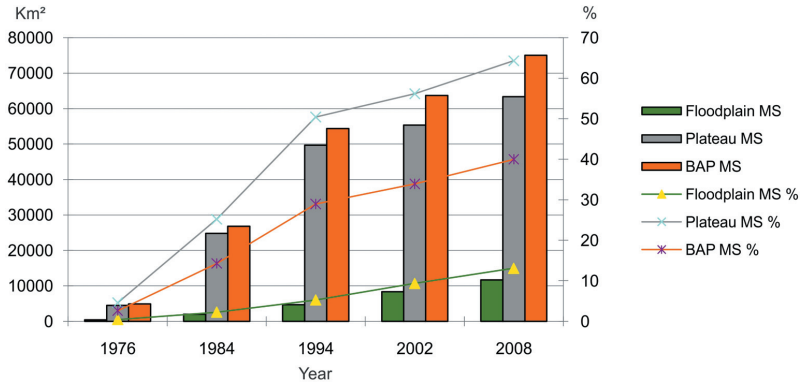

Figure 5 – Accumulated deforested area in the State Mato Grosso do Sul localized at BAP in the period from 1976 to 2008

The deforestation in the biomes at the Upper Paraguay river basin

Analyzing the graphs of figure 6, one verifies precisely the contribution, on absolute values, of the deforestation occurring on the Cerrado biome for the total of the area deforested in the basin. Based on data from table 1, the deforestation in the Cerrado represents 70.6% of the natural vegetation suppression occurred at BAP, and the remaining occurs on portions of the biomes Pantanal (15.5%) and Amazon (13.9%). One observes that the deforestation occurred in the Pantanal biome has a quite similar behavior to what occurred in the Amazon one, with quite close absolute values over time. Nevertheless, when one compares the deforestation of each biome proportionally to its area at the BAP, the behavior is quite different. While at the entire Pantanal biome only 15.2% of the natural vegetation was suppressed till 2008 in partial areas of the biomes Cerrado and Amazon present at BAP, the suppression of natural vegetation reached till this date respectively 58.3% and 66.7% of its territories.

On the plateau and in the Cerrado biome there was a light reduction on the intensity of deforestation in the period from 1994 to 2002 (Figure 6), what is reflected in the basin as a whole, since the Cerrado occupies the largest territory of BAP. In the Amazon biome one notes a little tendency for the reduction of accumulated deforestation between 2002 and 2008, perhaps because this part of the biome in the BAP reached its occupation limit. Such fact can be confirmed by the small inflection observed on the curve from the deforestation evolution at this biome (Figure 6) since 1994.

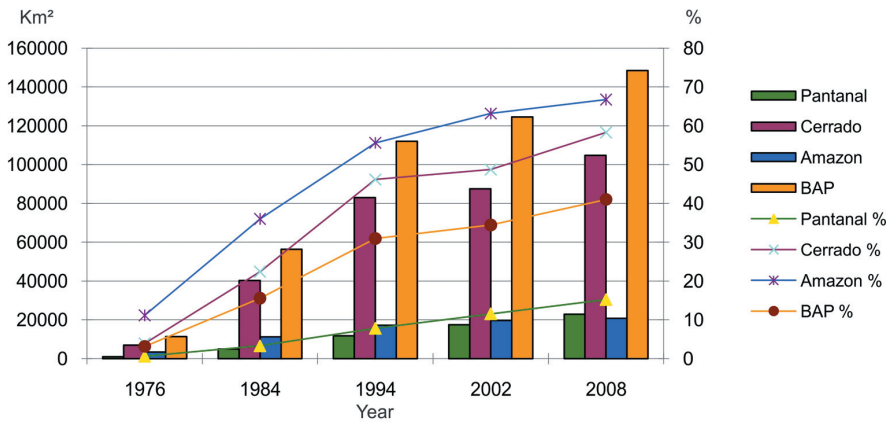

Figure 6 - Accumulated deforested area in the portion of the biomes localized at BAP in the period 1976 to 2008

The deforestation in the Pantanal floodplain and in the Pantanal biome

The behavior of the curve from the deforestation evolution in the Pantanal floodplain and in the Pantanal biome (Figure 7) is similar, but the biome presents higher deforestation values along the period analyzed, both in absolute and relative numbers.

Using data from table 1 we calculate that, in relation to its physical area, in the Pantanal biome, the loss of natural area reached 0.6%, 3.3%, 7.8%, 11.5% and 15.2% till respectively 1976, 1984, 1994, 2002 and 2008.

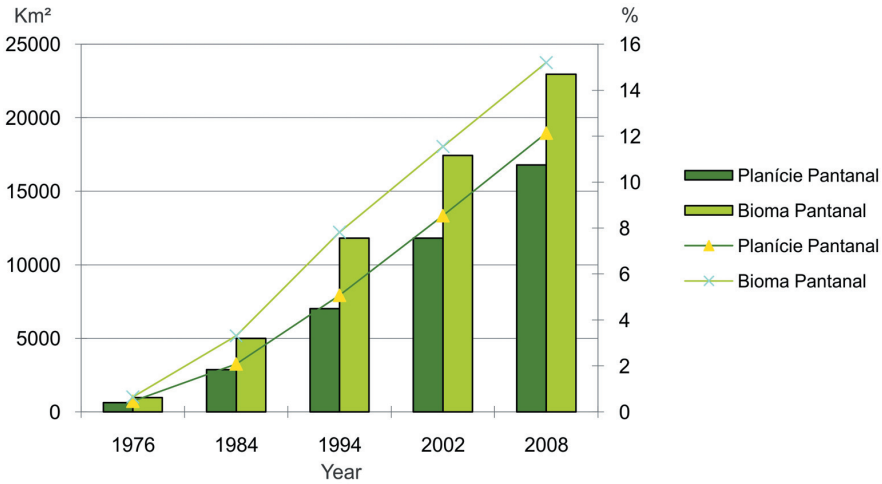

Figure 7 – Accumulated deforested area in the Brazilian Pantanal at BAP in the period from 1976 to 2008

One verifies that the deforestation in the floodplain increased 26,5 times in the period 1976-2008, while at the biome this rate attained 23,6 times, in relation to its physical area. However the deforested area in the biome in 2008 is 36.7% higher to the figure in the floodplain, reaching till now 22,959.4 km^2.

Referring to the deforestation at the basin till 2008, the floodplain known as Pantanal corresponds to 11.3% of the deforested area, but considering the biome, it corresponds to 15.5%.

Spatial evolution of deforestation at BAP

For the spatial analysis of deforestation at BAP, figures 8 and 9 were prepared where it is possible to check the distribution of deforested areas at distinct sub-divisions of the area under study.

Analyzing these figures it is easy to verify how the pressure for deforestation in the basin occurs on the plateau, whether considering the Pantanal floodplain or the Pantanal biome. However, when the floodplain is considered (Figure 9) one verifies the occurrence of strong deforestation in the south of the Pantanal and when one considers the biome (Figure 8), to this area is summed up the NW section of the biome, localized to the West of the Cáceres city. The central objective of these figures is to show to the reader the spatial evolution of deforestation in specific areas, without intending to show details of this evolution.

Proportionally the deforestations are quite similar when compared to the sections of the Pantanal floodplain localized in each of the two States. There is a little difference of 1.1% in this proportion for the floodplain located in Mato Grosso do Sul, because while 10.4% of the natural vegetation from this area were already suppressed till 2008, in the portion of Mato Grosso this occurs at only 9.3% of its territory.

Figures 8 and 9 show that in the period 1976-84 and 1984-94 most deforestation occurred at BAP, because large spaces in white at the figures were filled up by gray, the color considered for deforestation. However in the period 1984-94 the deforestation was higher in 23.5%. While in the first period 45,000 km^2 of natural vegetation was eliminated, in the second one the total reached 55,600 km^2. Two events are considered as inductors of

this event, as already commented by Silva et al. (2005): the National Plan for the Land Reform (PNRA 1985-1989) and the promulgation of the Federal Constitution of 1988. While the PNRA prioritized the re-establishment of the Land Reform, the Constitution foresees the expropriation of land for this objective in the rural properties which did not comply with its social function.

In relation to the biomes which compose BAP, comparing figure 1 with 8, one identifies the occurrence of the deforested areas at its respective portions. Even if lightly, one verifies at figure 8 that there isles space without deforestation in the area related to the Cerrado biome than at the Amazon biome till the year 2008.

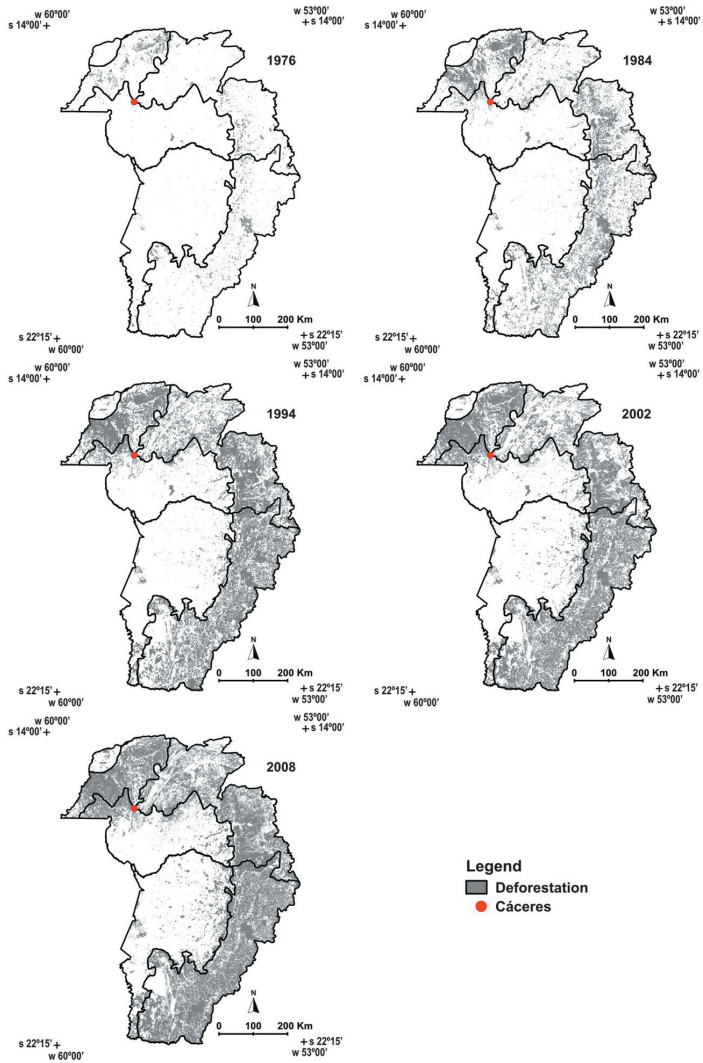

Figure 8 – Deforestation at BAP and biomes in the period from 1976 to 2008

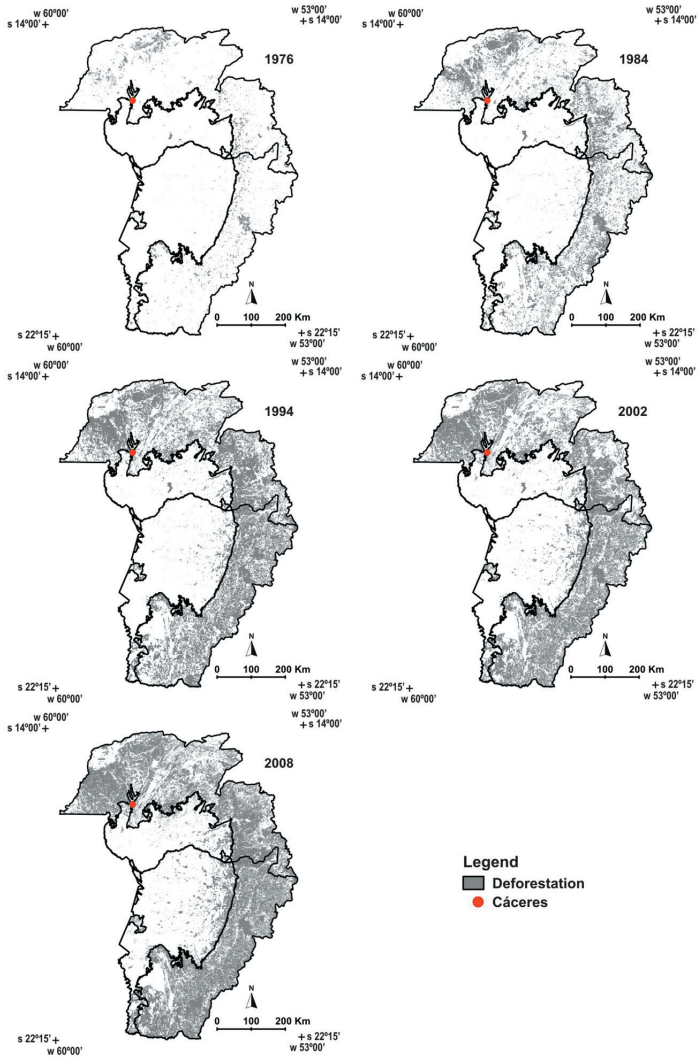

Figure 9 – Deforestation at BAP and at the floodplain in the period from 1976 to 2008

Estimation of tendencies of deforestation at BAP and its sub-divisions

To analyze the tendency of deforestation at BAP and its several territorial portions, average rates of geometric growth were elaborated for the periods 1976-1984, 1984-1994, 1994-2002 and 2002-2008 (Table 2). Based on these data, figures 10,11,12 and 13 were elaborated, showing the evolution of these rates along time.

Table 2 - Average rates of geometric growth at BAP and sub-divisions in the four periods analyzed

Physiographic delimitation	Average rates of geometric growth			
	1976_84	1984_94	1994_2002	2002_08
BAP (floodplain/plateau)				
Floodplain	0.208	0.093	0.067	0.060
Plateau	0.222	0.070	0.009	0.026
BAP Brazil	0.221	0.071	0.013	0.030
BAP (States)				
BAP MT	0.208	0.069	0.007	0.031
BAP MS	0.237	0.073	0.020	0.028
BAP Brasil	0.221	0.071	0.013	0.030
BAP (Biomes)				
Pantanal	0.227	0.090	0.050	0.047
Cerrado	0.245	0.075	0.007	0.030
Amazon	0.158	0.044	0.016	0.009
BAP Brazil	0.221	0.071	0.013	0.030
Pantanal (Floodplain/Biome)				
Pantanal floodplain	0.208	0.093	0.067	0.060
Pantanal biome	0.227	0.090	0.050	0.047
BAP Brazil	0.221	0.071	0.013	0.030

One observes at table 2 and figures 10 to 13 that the highest growth rates of deforestation occurred in the period 1976 to 1984. Except for the Amazon biome which presented yearly growth rates of 16.8%, for BAP and the other territorial portions composing it, the growth rates were above 20% per year.

The evolution of the growth rates for the floodplain, the plateau and BAP can be verified at figure 10. The Pantanal floodplain presents a decrease on the deforestation speed in the four periods analyzed while at the plateau and BAP the rates reduced continuously till 2002, but went up in the period from 2002 to 2008.

At the analysis of the average rates of geometric growth of deforestation in the biomes (Figure 11) which compose the BAP, the Pantanal and Amazon biomes also present a continuous decrease in the deforestation rates during all periods analyzed. However the Cerrado, after presenting a fall of rates till 2002, suffered an increase in the period 2002 to 2008. At figure 12 one observes the evolution of deforestation growth rates in the territorial portions of States present at BAP. In this analysis one sees also the same tendency of speed reduction from deforestation till 2002, and an increase in the period from 2002 to 2008. The increase verified in the period is associated to land use because, according to Santos & Câmara (2002), in those upstream of Pantanal, the soybean monoculture destined to export expanded, as well as sugarcane for the production of bio-fuels, causing indirectly in this region, negative social-economic effects, typical for this type of agricultural exploitation. It is important to consider that on the upriver areas of Pantanal there are several wellsprings which contribute directly to the maintenance of the inundation pulse. Accordingly the

deforestation on the headwaters caused a significant increase on sedimentation, resulting in the reduction of both soil and pasture productivity and on the increase of the frequency and level of flooding (LOURIVAL et al., 2000). The great biodiversity of the Pantanal is associated to the inundation regimen which keeps large areas flooded during periods varying from 6 to 12 months.

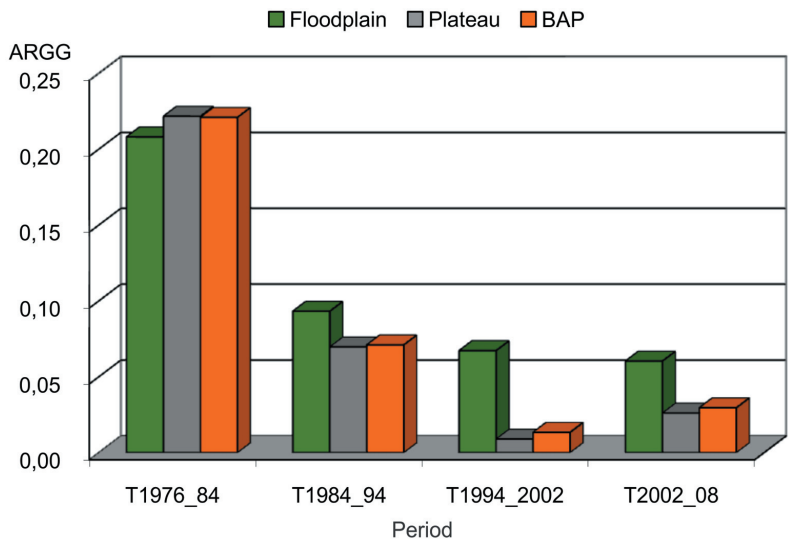

Figure 10 – Evolution of the average rate of geometric growth (ARGG) of deforestation in Brazilian BAP in the period 1976 to 2008

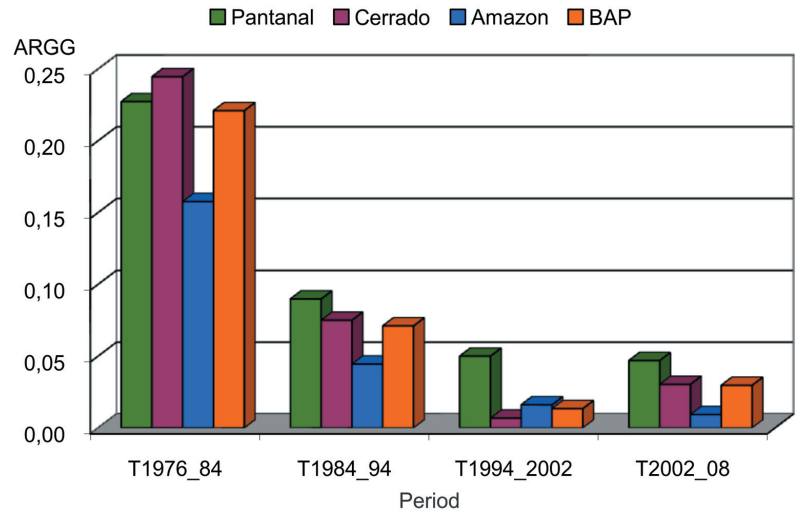

Figure 11 – Evolution of the average rate of geometric growth (ARGG) of deforestation in the Brazilian BAP biomes in the period 1976 to 2008

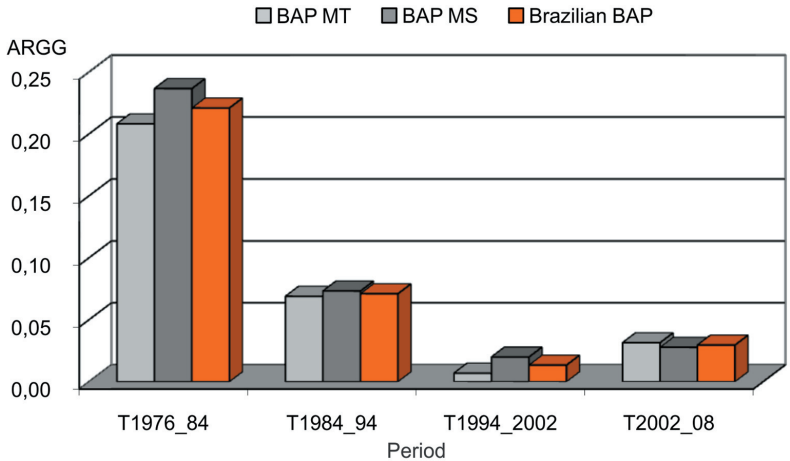

Figure 12 – Evolution of the average rate of geometric growth (ARGG) of deforestation in the States of Brazilian BAP in the period 1976 to 2008

Figure 13 shows in more detail the evolution of the deforestation growth rates in the biome and Pantanal floodplain. It is noteworthy that in these two territorial portions the tendency is the reduction of the deforestation speed that is different of the rate at BAP which, due to the deforestation on the plateau has a tendency of growth in the last period.

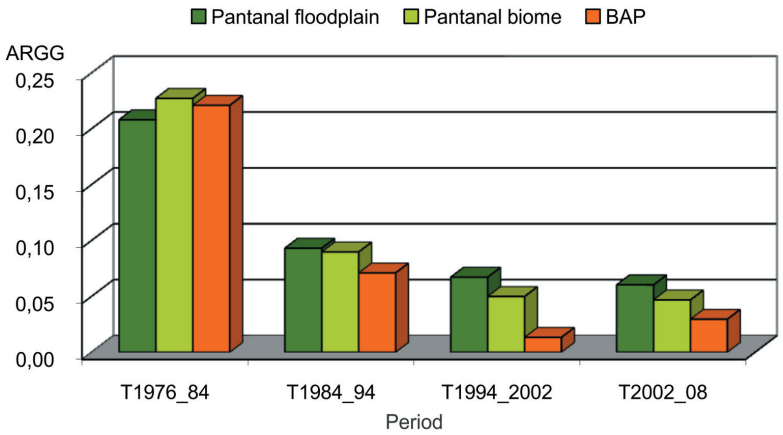

Figure 13 – Evolution of the average rate of geometric growth (ARGG) of deforestation in the Pantanal floodplain and on the biome Pantanal in Brazil in the period 1976 to 2008

Based on the average geometric growth rates it is possible to trace probable scenarios of deforestation for BAP and its sub-divisions. Using the rates of the period 2002 to 2008, figure 14 was elaborated with the scenario of deforestation from 2010 to 2050 for the Pantanal floodplain, the plateau, BAP and the Pantanal biome. If the present conditions

remain, the tendency is the suppression of the natural vegetation from the plateau of BAP till 2029 (i.e. in the coming 19 years) and of the floodplain till 2045 (i.e. in the coming 40 years). The study made by Harris et al. (2006) corroborates the scenario presented in our study. The authors used the deforestation rate of 2.3% per year (considering the period 2000-2004) and concluded that within a little over 45 years (2051) the original vegetation cover of the Pantanal will be completely lost or modified, so that it will be improbable to reconstitute the climatic-hydrologic complex, the exuberance of the waters and the rich regional biodiversity.

In the MMA (2006) report there is an alert about the increase of deforestation, mentioning that the forecasts demonstrate that by 2020 there could be an increase of population at BAP up to 2,250,000 inhabitants and in 2050 up to 3,920,000, which certainly would cause further problems [...] If the attention given to land use up to now would occur with the same perspective without planning, there would be an increment of deforestation by the occupation of new land for agriculture, which would increase the commitment of water resources by contamination of water sources and silting of rivers.

However the forecast presented eventually will not become concrete, considering that actions can be taken and the legislation implemented by governmental agencies, which must be more incisive in the control and monitoring of deforestation in the Pantanal.

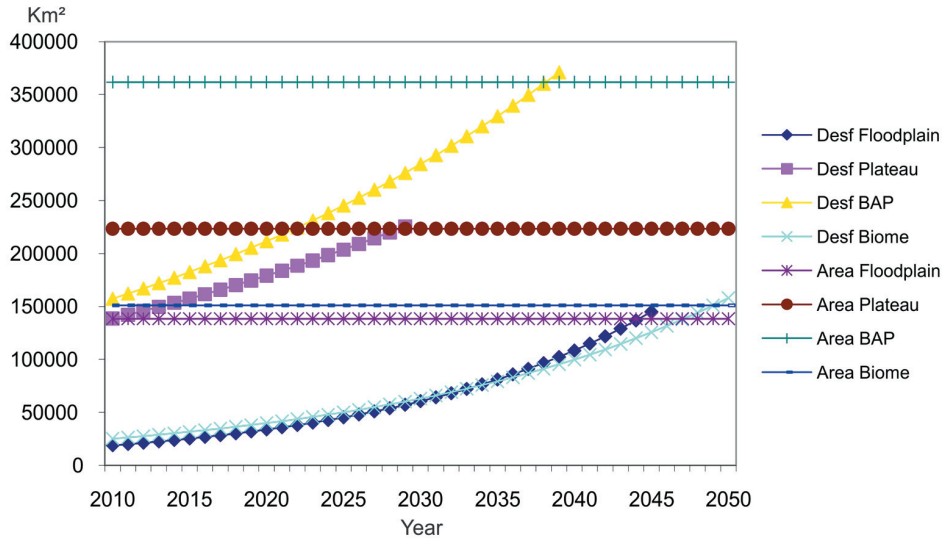

Figure 14 – Deforestation scenarios for the Pantanal floodplain, the plateau, BAP and the Pantanal biome for the period 2010 to 2050

Presently BAP does not have a monitoring system for the deforestation, neither a structured geo-referenced information base. It is noteworthy that the Brazilian Federal Government conducts the world largest program to monitor deforestation in the Amazon region, but this program does not include the Pantanal, because it is not localized in the region defined as "Legal Amazon". The National Institute for Space Research (INPE) developed efforts since the 90s to monitor the deforestation in the Amazon region (generation of maps, calculation of deforestation rates, making results available, etc.), contributing strongly for the definition and transference of methodologies used (DUARTE et al., 1999; SHIMABUKURO et al, (1998, 2005); CÂMARA et al., 2006, DUARTE et al., 2006). Such methodologies can be

adapted to the Pantanal region, creating a monitoring system for the Pantanal basin. This is feasible, if there is political interest to its realization. It is a fact that there is a growing demand of uses for production and infrastructure which generate pressures on the BAP region, allowing land use and occupation without integrated planning, executed on fragmented form by public policies for both States Mato Grosso and Mato Grosso do Sul, considering distinctly the hydrographic region and dissociating the relations existing among the form of land use on the floodplain and plateau regions (MMA, 2006).

In order to do that, we propose that such a system to monitor the dynamics of deforestation in the Pantanal is elaborated applying information technologies, based on free software and geo-technology tools (remote sensing, GIS, geo-referenced databanks, consultation and release of data by Web).

Finally we agree with Santos & Câmara (2002) that the scenarios generated by this study constitute possible images for the future, which will be the result of decisions taken presently.

CONCLUSIONS AND SUGGESTIONS

Deforestations are occurring systematically on the plateau adjacent to the Pantanal, causing impacts on it, considering the floodplain or the biome. The deforestation occurs in a larger extension and velocity on the plateau than at the Pantanal floodplain, and this suggests preventive and incentive decisions to minimize its effects on the environment, because the deforestation on the plateau influences directly the Pantanal.

Between 1976 and 1984 the deforestation occurred at a higher speed, decreasing till 2002, but presenting an increase in the period 2002 to 2008.

Historically the floodplain is known as Pantanal, but with the delimitation of the biome in a generalized scale and including portions beyond the floodplain, the total deforestation tends to increase, as shown in this work.

Overestimated deforestation values for the Pantanal result in unrealistic rates and tendencies, penalizing those who conserve the region and inducing the creation of wrong public policies.

The analysis and estimations of impacts due to the conversion of natural areas to land use, must always consider the adjacent plateau, since there is a synergism between these two territories. Similarly the development plans or programs to be implemented in the region must foresee this synergism.

Considering any delimitation for the analysis of deforestation at BAP, and if the present conditions remain, the natural vegetation from the region will disappear in the next 40 years, i.e. till 2050. Nevertheless, changes on attitudes of society and the requirement of fulfillment from legislation by governmental agencies, are capable to change the prognostic presented for the future of BAP.

We recommend the implantation of a monitoring system for deforestation in the Upper Paraguay river basin based on technology information, so that the scenario could be changed, according to what is done in the Amazon region.

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