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CONVERSION OF FORESTS AND WOODLANDS TO CULTIVATED PASTURES IN THE WETLAND OF BRAZIL

CONVERSIÓN DE BOSQUES A PASTIZALES CULTIVADOS EN EL PANTANAL, BRASIL

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ABSTRACT

An aerial survey of the Pantanal, Brazil, shows that the largest wetland in the world is under threat of deforestation. The fauna depends on the forested area which originally covered only 30% of the region. Deforestation ranges from 1% to 18%, depending on the subregion, with a total of 6,260 km^2 in 1991. Deforestation is concentrated along the eastern and northeastern border of the Pantanal, recently increasing towards the center of the floodplain. Recent deforestation is occurring at an exponential rate.

Key words: Pantanal, deforestation, aerial survey, wetland, pastures, Brazil

RESUMEN

Un levantamiento aéreo en el Pantanal, Brasil, demostró que la mayor área húmeda del mundo sufre amenazas por la deforestación, comprometiendo la fauna que depende de los 30% del área con bosque en la región. El porcentaje de deforestación varió de un 18% al 1% de acuerdo con la subregión, totalizando 6.260 km^2 en el año 1991. Las deforestaciones se concentran en los bordes este y oeste, con acentuado avance hacia la parte central de la planicie. Nuevas deforestaciones indican una tasa de desmonte exponencial.

Palabras clave: Pantanal, deforestación, levantamiento aéreo, humedal, pasturas, Brasil.

INTRODUCTION

The Brazilian Pantanal is the largest wetland in the world (140,000 km^2) and was designated a World Heritage Site by UNESCO in 1985. Settlement of the Pantanal took place 250 years ago with the introduction of cattle sustained by native grasslands. Then, livestock became an important activity, which still constitutes the major economy of the region. Recently, however, the Pantanal has begun a process of deforestation cultivated pastures. These modifications in land-use patterns have several causes, including the need by ranchers to increase cattle productivity, due to the present multi-year wet cycle that began in 1974 (Cadavid-Garcia 1984). The most affected forest areas are located on ancient levees or *cordilheira,* corresponding to the highest elevations at approximately 2 meters, above the plain and generally flood free. The levees of forested areas are considered for the landownership. Their spatial distribution varies throughout the Pantanal and may depend on the geographic region.

The simplification of this ecosystem following deforestation has deleterious effects on faunal communities, which are dependent on these areas for feeding and shelter. The Pantanal possesses a diverse fauna, and is well known for its abundance of terrestrial and semi-aquatic vertebrates such as capybara (*Hydrochaeris hydrochaeris*), giant anteater (*Myrmecophaga tridactyla*), jaguar (*Panthera onca*) and caiman (*Caiman crocodilus*). Several of these animals are considered endangered, and for some the Pantanal may represent one of the last refuges.

Alho *et al*. (1988) and others have called attention upon the dangers of deforestation in the Pantanal, but there is no information about its

Figure 1. Map of the Pantanal in Brazil with the specification of subregions in the upper basin of Alto Paraguay.

distribution and extension. Ground surveys in the Pantanal are very difficult and sometimes impossible because of large floodings and absence of roads. We used aerial survey by a light aircraft to estimate rates of deforestation and proportions of various types of arboreal vegetation affected by this action in the Pantanal.

MATERIALS AND METHODS

Study area

The Brazilian Pantanal is an inmense sedimentary floodplain with an area of about 140,000 km^2. It is part of the Paraguay River Basin located between 16º and 21º S and between 55º and 58º W, being part of 2 Brazilian states: Mato Grosso and Mato Grosso do Sul (Figure 1).

Climate is tropical with a dry winter season (Aw, according to Köppen) with an alternation of wet and dry periods (Cadavid Garcia 1984). Rainfall varies between 1,000 and 1,400 mm/year; 80% of this occurs from November through March.

The very gentle slope of the Pantanal impedes rapid drainage and results in a mosaic of deep and shallow flooding as well as areas which remain dry throughout the year. Such mosaic has areas regionally known as *vazantes* of seasonally intermittent streams; *baías*: ponds, both permanent and temporary; *salinas*: brackish ponds, surrounded by semideciduous forests; *corixos*: permanent streams; *cordilheira*: ridges of slightly elevated ground (1-2 m above grassland level) bearing forest or *cerrado* (a distinctive savanna community; grass cover is dense and there is a scattering of flow gnarled trees, where tree cover is denser, this is often called *cerradão*), and *capões*: smaller isolated woods, rarely subject to flooding (Ratter *et al*. 1988).

Soils are predominantly hydromorphic (92.5%), composed of sands and clays from sedimentary origin occurring in an alternating pattern (Amaral Filho 1986).

According to Prance and Schaller (1982), the Pantanal is delimited to the east by the *cerrado* of Central Brazil, fringed to the northwest by semideciduous forests related to the Amazonian forest, and is delimited to the southwest by the dry chaco-like forest of neighboring Bolivia and Paraguay. Within the Pantanal region, there are habitats suited to *cerrado*, semideciduous forest, xeric scrub, and gallery forest. Formations of drier vegetation are interspersed with various types of swampy vegetation in flooded areas.

A regional scale aerial survey was used to determine the extension of deforestation in the present study. It was done in conjunction with a faunal survey to determine patterns of wildlife distribution and abundance (Mauro 1993, Mourão 1996).

Cultivated pastures during the survey were recorded as previously deforested land (before 1991), since they were planted only on originally forested land. We considered areas with cultivated pastures as being deforested before 1991, observing directly these patches from the aircraft. Sown pastures are very different from native grasslands and easily recognized.

We used a Cessna 206 aircraft, flying at an altitude of 60m above ground level at a speed of 200 km/hr. Flights took place between September 1 and October 13, 1991. The Pantanal was divided into 6' (latitude) transects. Total flight time was

Table 1. Equivalence among the physiognomic/ecological system of IBGE (1992) and local name.

Physiognomic/ecological system of IBGE (1992)	Local name
Seasonal semideciduos alluvial forest	gallery forest
Lowland seasonal semideciduos forest	semideciduos forest
Savanna forest	cerradão (dense savanna woodland), babaçual (*Attalea speciosa*) palmary
Savanna woodland	cerrado
Park savanna	paratudal (*Tabebuia* woodland), canjiqueiral (*Byrsonima* woodland with shrubs)
Grassy savanna with low shrubs	wet grassland, dry grassland
Chaco savanna woodland	chaco
Chaco park savanna	*Copernicia alba* woodland
Soil-related pioneer formations – Vegetation associated with riverine or lacustrine habitats	buritizal (*Mauritia flexuosa* palmary), cambarazal (*Vochysia divergens* woodland), swamp

about 100 hours. We attached a rod under each wing to visually delimit the sample area. We observed and characterized the habitat directly located under the aircraft every 36" (longitude), approximately 1 km.

The system proposed by Adámoli (1982) dividing the Pantanal into 10 subregions based on intensity of flooding and vegetation types, was used for data analysis.

A correlation for classifying the vegetation according to the local name and the physiognomic/ecological system nomination given by IBGE (1992) was established (Table 1).

RESULTS

Sampling the main vegetation types of the Pantanal (percentage)

Table 2 presents percentages per subregion of the main types of vegetation in the Pantanal. The forested areas are represented by *cerradão*, *cerrado*, *Tabebuia* woodland (predominance of

Table 2. Vegetation type in the subregions of the Pantanal, as percent of total are, where 1= Cerradão, 2= cerrado, 3= semideciduous forest, 4= *Tabebuia* woodland, 5=*Copernicia* woodland, 6=*Byrsonima* woodland, 7=swamp, 8= flooded field, 9= dry field, 10= chaco forest, 11= gallery forest, 12= others.

SUBREGION	1	2	3	4	5	6	7	8	9	10	11	12
Cáceres	36.8	11.1	0.5	0	0.8	2.8	4.7	12.9	12	0	1.2	17.2
Poconé	12.9	7.9	12.6	0.3	0.8	1.3	17	16.8	9.8	0	4.3	16.3
Barão de Melgaco	22.3	35.8	4.8	0	0	0.6	6.1	3.5	4.4	0	5.2	17.3
Paiaguás	23.7	17.4	2.3	0	0.03	1.4	6.6	12.5	14	0	2.4	19.7
Nhecolândia	33.5	11.9	1.1	0	0	0.3	0.3	2	20.1	0	0	30.8
Aquidauana	31.2	20.2	2.9	0.4	0	2.5	5	3.5	7.9	0	3.9	22.5
Miranda	30.8	14.7	14.4	6.4	3.5	0	10.6	2.3	8	0	2.3	7
Abobral	15.4	1.2	3.3	3.6	1.8	2.1	10.3	15.7	19.3	0	0.9	17.4
Nabileque	0.3	0	0.7	14	19.1	1.3	12.3	21.4	13.5	6.7	0.7	10
Paraguay	0	0	2.7	0.7	0.6	0	35.5	22	2	0	6.7	29.8
Pantanal	22.1	14.3	3.9	1.7	2.3	1.2	7.4	10.8	12.4	0.5	2.4	21

Table 3. Deforested habitats in the Pantanal, as percent of the subregion area.

HABITAT	*cerradão*	*cerrado*	semi-deciduous forest	*Tabebuia* woodland	*Copernicia* woodland	gallery forest	chaco forest
SUBREGION	before 91 - 1991	before 91 - 1991	before 91 - 1991	before 91 - 1991	before 91 - 1991	before 91 - 1991	before 91 - 1991
Cáceres	15.8 - 3.2	11 - 0	0 - 0	0 - 0	0 - 0	8.3 - 0	0 - 0
Poconé	6.1 - 0.6	3.2 - 0.8	7.5 - 0	0 - 0	0 - 0	0 - 0	0 - 0
Barão de Melgaço	7.7 - 2.3	5 - 0.8	1.5 - 1.5	0 - 0	0 - 0	1.4 - 0	0 - 0
Paiaguás	3.9 - 2.7	0.6 - 3.3	0 - 0	0 - 0	0 - 0	1.5 - 4.5	0 - 0
Nhecolândia	8.3 - 8.9	2.3 - 9	0 - 4.8	0 - 0	0 - 0	0 - 0	0 - 0
Aquidauana	17.5 - 1.3	9.7 - 6.8	0 - 0	0 - 0	0 - 0	20 - 0	0 - 0
Miranda	18.6 - 17.8	0 - 0	22 - 10	13.7 - 0	9.8 - 18.7	0 - 0	0 - 0
Abobral	2 - 0	0 - 0	0 - 0	0 - 0	0 - 0	0 - 0	0 - 0
Nabileque	0 - 0	0 - 0	4 - 9.3	0 - 0	1.4 - 2.3	0 - 0	3.9 - 9.2
Paraguay	0 - 0	0 - 0	25 - 0	0 - 0	0 - 0	0 - 0	0 - 0
PANTANAL	17.1 - 6.7	4.5 - 4.1	5.2 - 2.3	1.2 - 0	0.1 - 1.9	2.7 - 0.4	0.2 - 0.6

Tabebuia aurea), *Copernicia* woodland (predominance of *Copernicia alba*), *Byrsonima* shrubs (predominance of *Byrsonima orbignyana*), chaco forest, and gallery forest.

Forested areas represent, on the average, 30% of the total area. The subregions of Miranda and Paraguay are exceptions, with 55% and 5% of forested land, respectively.

Cerradão was the most frequently represented, followed by *cerrado*, dry grassland, and flooded grassland (with the last two classifications varying, depending on the season and the year in which the areas were classified).

The Nabileque subregion had the most varied vegetation, with extensive areas of *Tabebuia* woodland (14%) and *Copernicia* woodland (19%). These vegetation communities were also present in the Miranda and Abobral subregions, though in lower proportions.

The community of semidecidous forest type occured most frequently in the subregions of Miranda and Poconé, comprising 14% and 12.6% of these areas, respectively.

Areas with cultivated pasture and deforestation

In 1991, the observed deforested areas were considered additional areas to already existing pasture areas (Table 3).

Before 1991, *cerradão* was the native vegetation most frequently replaced by cultivated pastures (Table 3). This was true throughout the Pantanal, except in the Nabileque subregion, where chaco forests were more frequently used, and in the Poconé subregion, where *cerradão* and semideciduous forest were used at about the same intensity as *cerradão*.

In 1991, *cerradão* continued to be the most heavily deforested vegetation type in most subregions. In the Miranda subregion, it was the *Copernicia* woodland and in Nabileque it was the chaco forest followed by the *Copernicia* woodland. No deforestation was observed in the Abobral and Paraguay subregions.

Semideciduous forest in the Miranda subregion showed a high replacement with 32% of cultivated pastures. 20% of the gallery forest of the Aquidauna subregion were also replaced with pastures.

In the Nhecolândia subregion, considering only the existing area of pasture from *cerradão* to pasture. As a result the area of cultivated pasture doubled, increasing another 8.8% on this vegetation type; the amount of *cerrado* under pasture doubled, deforesting an additional 9% of this landscape.

In the Miranda subregion, *cerradão* lost 5.5% of its area due to deforestation, and cultivated pasture thus increased by 95%, while semideciduous forest lost 32% of its area, with the amount of pasture replacing this vegetation type increasing by 50%.

Although the Nabileque subregion had only 1.1% altered area, the process was observed to be accelerating (Table 3, for semideciduous forest, *Copernicia* woodland and chaco forest). In the chaco forest, which represented 6.7% of the subregion, the deforested area increased by 230%.

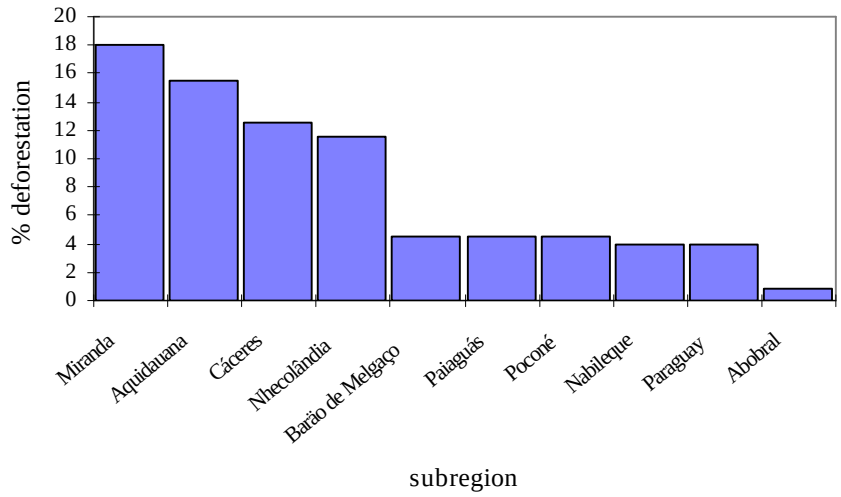

Figure 2. Percentage of deforestation in subregions Brazilian Pantanal.

Similarly, the deforested area of *Copernicia* woodland increased by 150%.

Combining cultivated pastures and general deforestation, and summing across all vegetation types, the total altered area is about 4.5% of the Pantanal, or approximately 6,260 km^2 showing a tendency toward higher growth between 1990 and 1991 ($y=0.763+1.278x$, $R^2= 0.832$, $n=70$, $F=335.64$, $P=0.001$). Proportionally, the Miranda subregion was the most affected (with 16.7% altered area), followed by Aquidauana, Cáceres and Nhecolândia, which showed alterations of 9.9%, 7.8% and 7.3%, respectively. The Paraguay and Abobral subregions remained unaffected, perhaps because they are flooded during most of the year.

When we consider only forested areas, which are virtually the only areas suitable for pasture conversion, the aforementioned indices increased for all subregions. The subregions of Miranda, Aquidauana, Cáceres, and Nhecolândia had lost, 18% 15.5%, 12.5% and 11.6% of their forests, respectively, due to deforestation and/or pasture cultivation. In the whole Pantanal, 8.6% of the originally forested land had been lost (Figure 2).

Spatial distribution of deforested areas and cultivated pastures

Figures 3 and 4 show that deforested areas and cultivated pastures are concentrated along the eastern and the northwest borders of the Pantanal, close to the town of Cáceres. In addition, deforestation has penetrated towards the center of the Pantanal in the subregions of Barão de Melgaço, Nhecolândia and Paiaguás. Along the western border of Pantanal, intensively flooded by the Paraguay River, there is much less cultivated pasture and deforestation.

DISCUSSION AND CONCLUSIONS

Of all human impacts in the Pantanal during recent decades, indiscriminate deforestation constitutes one of the worst. Until recently, however, deforestation had occurred mainly outside the Pantanal, on the surrounding highland. EDIBAP (1979) estimated 25,900 km^2 of deforestation in the High Paraguay River Basin, with a small percentage within the plain (Pantanal).

After 1974, during the present multi-year wet cycle, the total area of native pasture has decreased due to greater flooding and this caused more intensive deforestation on the plain. Nowadays, deforestation constitutes a major problem in the Pantanal with 4.5% (6,260 Km^2) of land deforested. This proportion may seem low when compared to other ecosystems, but it is rather high if we consider that only 30% of the Pantanal total area is naturally forested. Here the deforestation rate reaches 8,6% in these forested areas. The non-uniform distribution of forested areas might affect their rate of disappearance. This could be the case in the Paraguay subregion, where only 4% of the area is arborescent vegetation. Silva *et al*. (1998) in 1990/1991 using data from satellite images, quantified the total deforestation of the Pantanal as 5,437.73 Km^2 (3.9%). The difference with our own estimates may

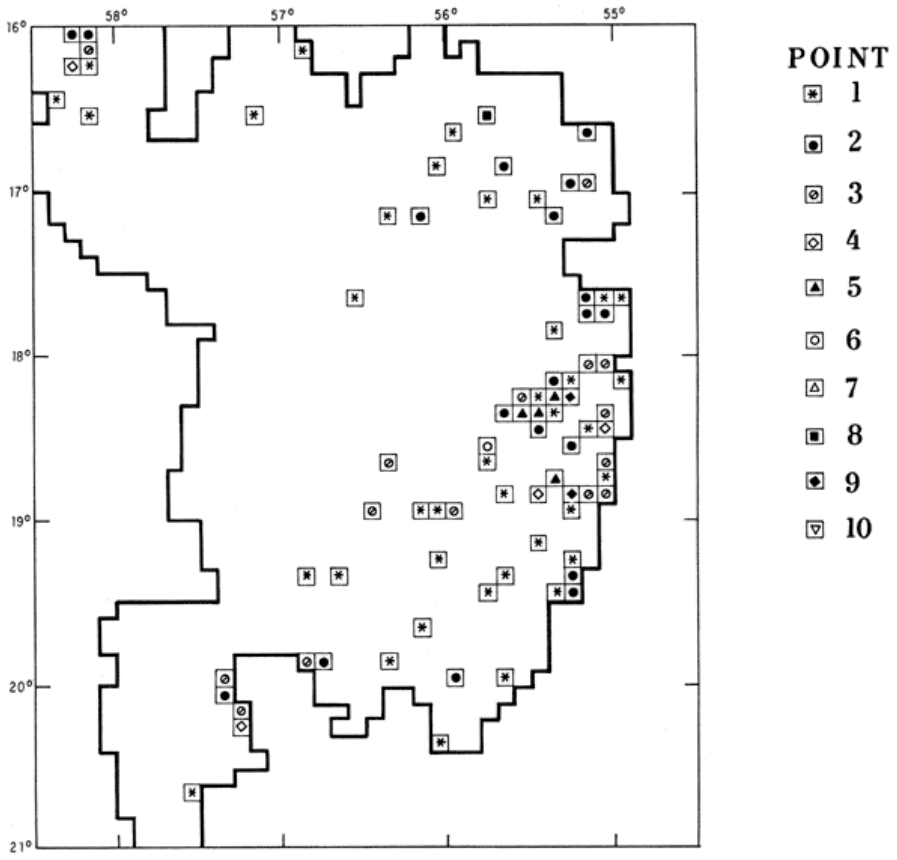

Figure 3. Distribution of deforested areas in the Brazilian Pantanal.

be due to disagreements in the limits of the Pantanal..

The concentration of deforestation along the east to the northwest border of the Pantanal reflects its proximity to several cities. The cause of deforestation may be in part a function of high ground, but the presence of cities probably facilitates local access to machinery. There are no towns within the Pantanal. The local concentration of deforestation could eventually isolate faunal communities in the Pantanal from the surrounding highland, interrupting dispersal corridors, which link the c*errado* biome to the west, or the Amazon to the northeast.

Deforestation for cultivating pastures is advancing towards the center of the Pantanal, particularly the *cordilheiras*, which are the forested areas in the central part. The destruction of these habitats may impact animal species, which in some way depend on these forests, and thereby eventually reduce biodiversity in the region. According to Schaller (1983), deforestation at Acurizal Ranch, in the Paraguay subregion, adversely affected the majority of wild mammal species in the area except for aquatic species.

The simplification of an ecosystem by deforestation can cause instability in the *status quo* of fauna, suppressing populations of some species and allowing invasion by others. Rham (1970) and Delany (1971) indicate that when the forest is removed, there are extensive changes in the local rodent populations, and this consequently influences the populations of predators at the top of the food chain. Campos (1993) verified that forests close to ponds in the Pantanal is the most important nesting habitat for *Caiman crocodylus yacare*, and that clearance might affect sex ratio of these crocodilians.

The worrisome thing about the deforestation process in the Pantanal is the speed at which it has begun to occur. In just one year (1990-1991), the area with cultivated pastures doubled or even quadrupled in certain subregions, depending on the plant communities which were replaced. The Miranda and Nhecolândia subregions have been the most severely impacted areas and already have

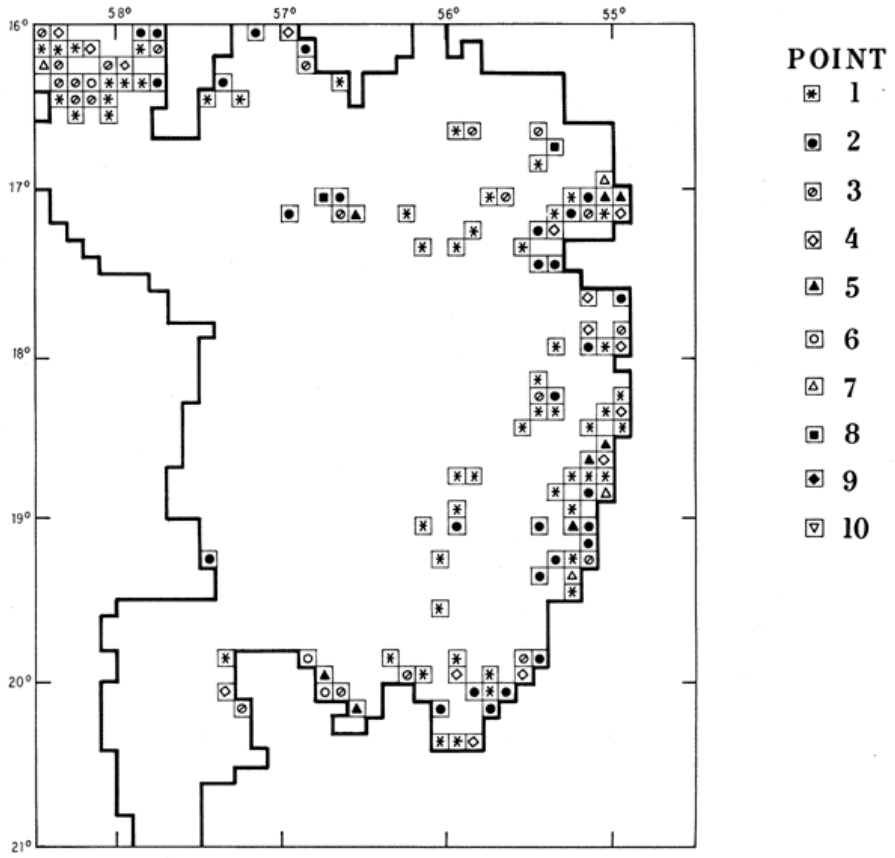

Figure 4. Distribution of cultivated pasture in the Brazilian Pantanal.

considerable transformation under cultivated pastures

At the present time it is not possible to predict the rate of increase in the Pantanal's deforestation for the coming years. The high rate of deforestation in 1991 might be related to the International Environmental Congress (RIO-92), which created an expectation among landowners that changes in Brazilian federal law could make land conversion more difficult.

The Forestry Code (Law 4771 of 1965) permits the conversion of 80% of native vegetation to cultivated pastures. Within the Pantanal, legal agencies consider areas with native pasture to be part of the 80%. This strict interpretation might have made landowners even more anxious to convert land in advance of anticipated legal changes. It should be noted that extensive deforestation has been brought about by agrocapitalists from other states that do not necessarily see ranching as a goal itself but only as another financial venture.

Fortunately, one limiting factor for pasture conversion appears to be the high costs of planting grassland.

Monitoring deforestation by aerial surveys will allow us to detect changes in the natural communities of the Pantanal as well as to determine correlations between densities of domestic animals and wildlife in general.

We have shown that the use of aerial survey methods to monitor environmental conditions (e.g. deforestation) is feasible. This information should serve as reference in making decisions by administrators and agencies of environmental control.

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