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# THE INFLUENCE OF HIGHWAY BR262 ON THE LOSS OF CERRADO VEGETATION COVER IN SOUTHWESTERN BRAZIL

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## ABSTRACT

The effects of a highway extending beyond the axis of the road, within regions with variable dimensions depending on the variables tested, are called "road effect zones". The limits can vary according to the landscape and in areas where human occupation is more intense and, especially where settlements are formed along the roads, there is an **accelerated rhythm** of environmental degradation through destructive exploitation. Currently, only 35% of the Cerrado biome remain unchanged for the Brazilian remnants, and the southwestern part of the biome mostly suffers from deforestation. During the '**80s**, in the State of Mato Grosso do Sul, there was a high rate of colonization and as a result vast areas of native vegetation were replaced by agricultural lands, such as cash crops and pasture. The objective of this study was to estimate the evolution of deforestation in the cerrado within a road zone effect of 200 km on the highway BR-262, between Campo Grande and Miranda (Mato Grosso do Sul State, Brazil). The effects were evaluated by using temporal and spatial analysis with geotechnology techniques and remote sensing data. Our hypotheses were that there is an evolution of deforestation since the 1980s, and that deforestation is more intense near the highway. The study area comprises 9 km (divided in three different distances) for each side of the road. This road begins in Brazil's central highlands and extends into the Pantanal, an environmentally important area. Based on satellite images from 1985 and 2001 we could estimate a 32.6% loss of cerrado along the highway. In addition, we found that the road impacts the distribution of vegetation cover, with pasture growing near the road, and forest cover growing further away. The roads are considered an accelerating factor to habitat degradation.
**Keywords:** Distance effect; landscape ecology; habitat fragmentation; road effect zone.

## RESUMO

**INFLUÊNCIA DA RODOVIA BR-262 NA PERDA DA COBERTURA DE VEGETAÇÃO DE CERRADO NO SUDOESTE DO BRASIL.** Os efeitos da rodovia que se estendem para além do eixo da estrada, com regiões de dimensões variáveis dependendo da variável testada, são chamados de "zonas de efeito da rodovia". Os limites podem variar de acordo com a paisagem e em áreas onde a ocupação humana é mais intensa e, especialmente onde assentamentos são formados ao longo da estrada, há um ritmo acelerado de degradação do meio ambiente por meio da exploração destrutiva. Atualmente, apenas 35% do bioma Cerrado permanecem inalterados para os remanescentes brasileiros e parte do sudoeste do bioma sofre principalmente com o desmatamento. Durante a década de 80, no Estado de Mato Grosso do Sul, houve uma alta taxa de colonização e, como resultado, vastas áreas de vegetação nativa foram substituídas por terras agrícolas como culturas de rendimento e pasto. O objetivo deste estudo foi estimar a evolução do desmatamento no cerrado dentro de uma zona de efeito da estrada em 200 km da rodovia BR-262, entre Campo Grande e Miranda (Mato Grosso do Sul, Brasil). Os efeitos foram avaliados por meio de análise temporal e espacial com métodos de geotecnologias e dados de sensoriamento remoto. Nossas hipóteses

eram que existe uma evolução no desmatamento desde os anos de 1980, e que o desmatamento é mais intenso nas proximidades da rodovia. A área de estudo compreende nove quilômetros (divididos em três escalas diferentes) para cada lado da estrada. Esta estrada começa no planalto central do Brasil e se estende para o Pantanal, uma área ambientalmente importante. Com base em imagens de satélite de 1985 e 2001, podemos estimar uma perda de 32,6% de cerrado ao longo da rodovia. Além disso, descobrimos que a estrada afeta a distribuição da cobertura vegetal, com o pasto se desenvolvendo próximo da estrada, e a cobertura vegetal crescendo mais distante. As estradas são consideradas um fator de aceleração para a degradação do habitat.
**Palavras-chave:** Efeito da distância; ecologia de paisagens; fragmentação de habitat; zona de efeito da estrada.

**RESUMEN**

**INFLUENCIA DE LA CARRETERA BR-262 EN LA PÉRDIDA DE LA COBERTURA DE VEGETACIÓN DE CERRADO EN EL SUDOESTE DEL BRASIL.** Los efectos de las carreteras que se extienden fuera del eje de la vía a regiones de dimensiones variables, dependiendo de la variable evaluada, son llamadas “zonas de efecto de la carretera”. Los límites pueden variar de acuerdo con el paisaje y, en áreas en donde la ocupación humana es más intensa, especialmente en donde los asentamientos son formados a lo largo del camino, hay un ritmo acelerado de degradación ambiental por medio de la explotación destructiva. Actualmente, apenas 35% del bioma Cerrado permanece inalterado en los remanentes brasileños y la parte sudoeste del bioma sufre principalmente con la deforestación. Durante la década de 1980, en el Estado de Mato Grosso do Sul hubo una alta tasa de colonización y como resultado vastas áreas de vegetación nativa fueron substituidas por tierras agrícolas, como cultivos comerciales y pastajes. El objetivo de este estudio fue estimar la evolución de la deforestación en el *cerrado* dentro de una zona de efecto de carretera de 200 km a lo largo de la carretera BR-262, entre Campo Grande y Miranda (Mato Grosso do Sul, Brasil). Los efectos fueron evaluados por medio de un análisis temporal y espacial con métodos de geotecnología y datos de sensores remotos. Nuestras hipótesis fueron que existe una evolución en la deforestación desde los años de 1980 y que la deforestación es más intensa en las proximidades de la carretera. El área de estudio comprende nueve kilómetros (divididos en tres distancias diferentes) para cada lado del camino. Esta carretera comienza en la meseta central de Brasil y se extiende hacia el Pantanal, un área ambientalmente importante. Con base en las imágenes satelitales de 1985 y 2001, pudimos estimar una pérdida de 32,6% de *cerrado* a lo largo de la carretera. Adicionalmente, descubrimos que la carretera afecta la distribución de la cobertura vegetal, con el pasto desarrollándose próximo a la vía y la cobertura forestal creciendo más distante. Las carreteras son consideradas un factor de aceleración de la degradación del hábitat.
**Palabras clave:** Efecto de distancia; ecología de paisajes; fragmentación del hábitat; zona de efecto de carretera.

## INTRODUCTION

The roads are the oldest forms of transportation which developed naturally from preexisting primitive trails that kept improving over time with bricks, rocks, wood and other oil mixtures, and also a drainage system that allowed better traffic conditions for people and for the flow/exchange of merchandise (Bustamante 1999).

There are multiple ecological effects of roads, as well as negative impacts that affect the fauna and flora, soil, vegetation cover, hydraulic system, and other factors that can extend meters away from the road or kilometers surrounding the area (Forman 1995). The road construction and consequently the cause of habitat fragmentation represent an important process in some of the species dynamics, which can result in extinctions (Laurance *et al*. 2001). In the state of Minas Gerais, the paving of BR-010, called “Rodovia Ecológica”, nearly caused the extinction of *Coccoloba cereifera* (Polygonaceae) (Viana *et al*. 2005).

The effects of the highway extend beyond the zone of the road. Forman (2000) classified this region, which can vary in dimensions depending on the variables tested, as “road effect zones”. In a suburban area of Massachusetts (U.S.A.), for example, the road-effect zone of the introduction of exotic species extended up to 100 m from the highway, while the effects caused by traffic noise on this highway caused injuries to birds of forested habitats 650m away, and to birds in open habitats up to 3m from the road (Forman & Deblinger 2000). These limits can vary according to the landscape, and an example occurs in the Brazilian Caatinga where the road effects on fragmentation and habitat reduction extends between 12 to 15m into the interior of the roadside vegetation (Santos & Tabarelli 2002). In the Atlantic Forest this effect was tested for distances up to 800m, with a significant increase in forest fragments 400m away from the highways (Freitas *et al*. 2009). In areas where human occupation is more intense, especially where settlements are formed along the roads, there is an **accelerated rhythm** of environmental degradation through destructive exploitation (Soares-Filho *et al*. 2004, Laurance *et al*. 2009). Currently, only 35% of the Cerrado biome remains unchanged for the Brazilian remnants, and the southwestern part of the biome most suffers from deforestation (Carvalho *et al*. 2009). During the **decade** of the **‘80s**, in state of Mato Grosso do Sul, there was a high rate of colonization, and as a result, vast areas of native vegetation were replaced by agricultural lands such as cash crops and pasture (Dias 1994, Klink & Machado 2005).

The objective of this study is to estimate the evolution of deforestation in the Cerrado within a road zone effect of 200km on highway BR-262. The effects were evaluated by using temporal and spatial analysis with geotechnical techniques and remote sensing data. Our hypotheses were that there is a continuous evolution of deforestation since the 1980s, and that deforestation is more intense near the highway.

## MATERIALS AND METHODS

This study was conducted on a 200km stretch of highway BR-262, and this portion covers an area between the cities of Campo Grande (-20°26’34”; -54°38’47”) to Miranda (-20°14’26”; -56°22’42”). The study area includes two Thematic Mapper (Landsat 5) images of point in orbit 225/074 and 226/74. To evaluate the temporal and spatial effects, two images of each point in orbit were selected: images of point in orbit 225/74 with landscape dates of 29/08/1985 (INPE 1985a) and 02/09/2001 (INPE 2001), and images of point in orbit 226/74 with landscape dates 21/09/85 (INPE 1985b) and 27/08/2002 (INPE 2002). Images were georeferenced to UTM, datum “Córrego Alegre”, the same used for the topographic maps from the IBGE/DSG. We used scenes with a one year difference in the landscape satellite image due to the presence of clouds in images of the corresponding years. We assumed that the temporal analysis for both 225/74 (2001) and 226/74 (2002) images corresponded, and with a 16 year interval between these images and 225/74 (1985) and 226/74 (1985) images.

Analyzing the images allowed us to quantify and evaluate the spatial distribution of the vegetation present in the region of the BR 262 highway stretch. Fragmentation of the cerrado forest, marshlands, grasslands and other phytophysiognomies found in the Cerrado biome are common in this region. For the identification of spectral signatures and vegetation cover quantification, a supervised automatic classification of the satellite images were conducted, adopting the 16 classes of soil cover proposed by Paranhos Filho (2000).

The categorized classes from the spectral classification were regrouped into three categories: pasture, cerrado and gallery forest. The urban areas have been photointerpreted as “urban area” (Figure 1) This procedure provides information on the occupied area by each soil cover class (Paranhos *et al*. 2008)

To analyze the effect surrounding the BR-262 landscape, three buffers were selected (a projected polygon from a point or line, with a predefined contour interval) and drawn from the highway axis: the first, encompassing an 1.5km transect for each side of the road; the second, encompassing a distance of 1.5 to 4.5km of the road, and the third, a distance of 4.5 to 9.0km. These three zones were established according to what was expected for the road zone ecological effects (Forman 2000) (Figure 1).

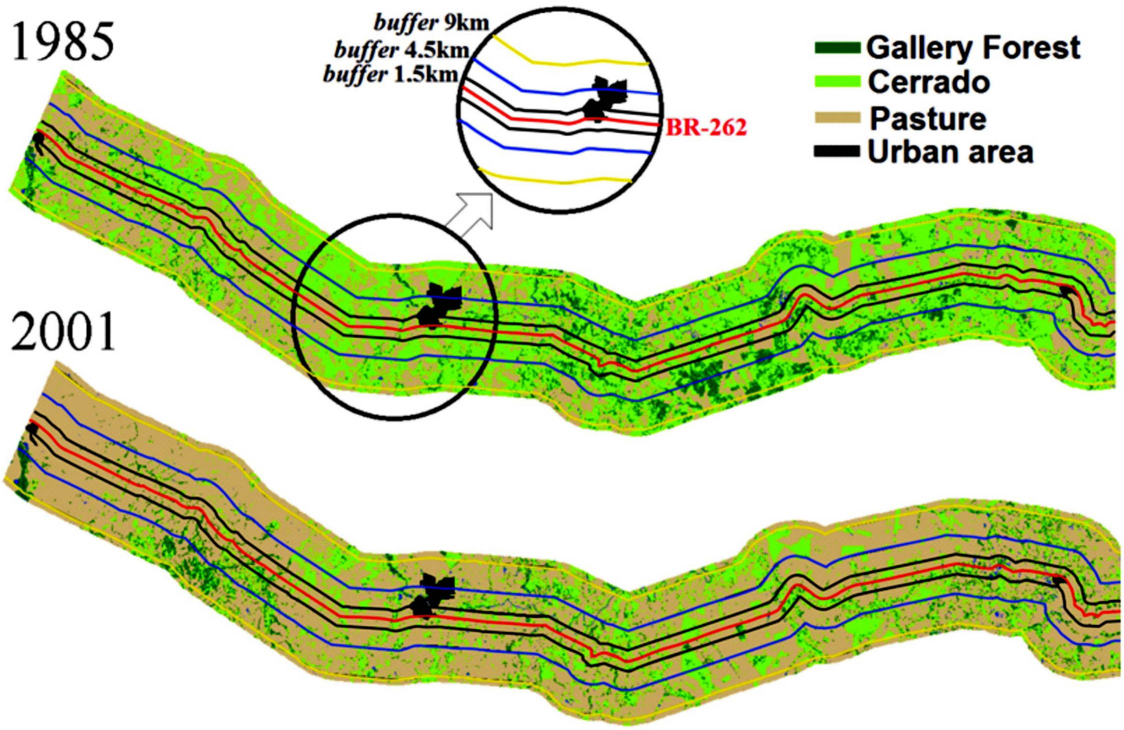


**Figure 1**. Landsat 5 satellite images of 1985 and 2001, classified and demarcated with 1.5km, 4.5km, and 9.0km buffer zones for each side of BR-262 (in red).

For each one of these buffers, we quantified the proportion of ground cover occupied by the cerrado, gallery forest, and pasture. The surface occupied by the rivers and urban areas were not considered because they represented a low percentage of the study area (< 5%). The buffers used served to compare the degree of deforestation as the road was being paved, and thus obtaining the highway effect on deforestation between the years 1985 and 2001/2002.

The treatment of the satellite images and the classification of ground cover were conducted using the ERDAS software Imagine 9.1 (ERDAS 1999) and PCI Geomatica 9.1 (PCI 2003).

*STATISTICAL ANALYSIS*

We evaluated the deforestation development over time using a G test (Zar 1984), comparing buffer to buffer for each year analyzed within one of the three distance scales evaluated, and with the three ground cover categories unified (cerrado, gallery forest, and pasture). This allowed us to obtain a general result of land-use along the years.

For the relation between ground-use and road distance, we calculated the relative area of each type of ground cover per year, dividing the total area for each group (pasture, gallery forest and cerrado, within each of three distance zones) by the total landscape study area. Then the expected value was multiplied by the relative area of each type of ground cover for a specific year by the area of each distance zone from the highway (0 – 1.5km; 1.5km – 4.5 and 4.5 to 9.0km); therefore, we considered the distribution of the different types of ground-use and cover, independent of the distance from the highway.

A G test was used to evaluate if there was a difference in the ground cover (cerrado, gallery forest, and pasture) within the three zones determined from the highway. Absolute data in hectares (observed results) was used to conduct the test. The null hypothesis was that the distribution of the different types of ground cover for each year was independent of the distance from the highway. If the test showed a significant difference between the expected and observed, the result would then indicate that a particular type of practice and ground cover is distributed in a distinct pattern between the distance zones from the highways; in other words, the road influences the distribution of this type of practice and ground cover.

## RESULTS

For the total area analyzed (zone 0 to 9.0km from the highway) between 1985 and 2001, there was a 32% and 3.4% loss of cerrado and gallery forest, respectively; in addition, there was an approximate increase of 34% for the pasture. This represents a median annual loss of 2.23% of forested area along this study site zone (Table 1, Figure 2).

**Table 1.** Relative area (%) of loss (-) or gain (+) in each distance zone for the years 1985 and 2001, in a road stretch between Campo Grande and Miranda, MS.

| | Distances (km) | | | |
|---|---|---|---|---|
| | 0 – 1.5 | 1.5 – 4.5 | 4.5 - 9 | 0 - 9,0 |
| Pasture | +28.27 | +36.30 | +34.94 | +34.20 |
| Gallery forest | - 1.53 | -4.09 | -3.61 | -3.40 |
| Cerrado | -30.23 | -34.78 | -32.98 | -32.20 |

The deforestation rhythm that occurred between the years 1985 and 2001 was significant for all the distance zones analyzed. The distance zone 0 to 1.5km had an approximate 32% loss of forested areas, and a gain in pasture area of 28 % (G = 12421.95; df = 2; P < 0.01). The distance zone, 1.5 to 4.5km, showed an approximate loss of 39% of forested area and a pasture growth of 36% (G = 34859.52; df = 2; P < 0.01). The greatest distance zone from the highway, 4.5 to 9.0km, had an approximate forest loss of 37 % , and a 35% pasture growth (G = 45700.62; df = 2; P < 0.01) (Table 1, Figure 2).

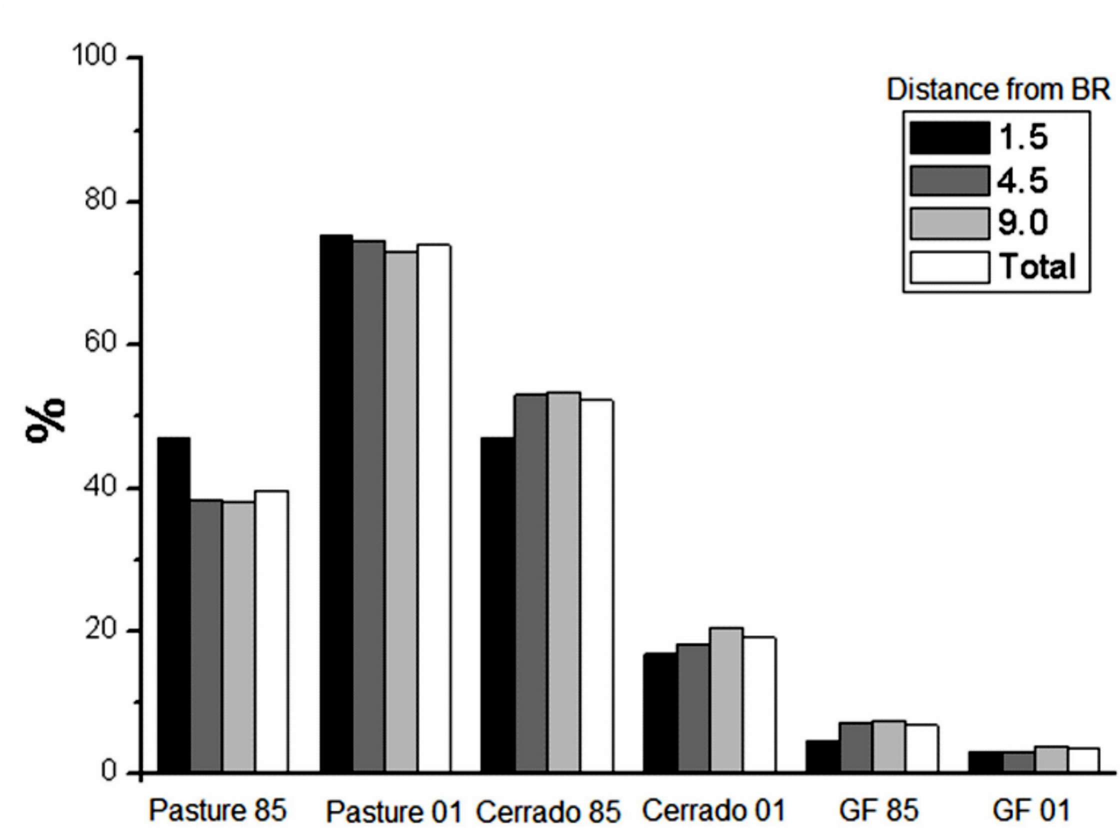


**Figure 2**. Percentage occupied by pasture, cerrado, and gallery forest (GF) in the evaluated road extension for 1985(85) and 2001(01) in different distances from BR-262.

There was a significant difference between observed and expected results for the distance zones of ground cover proportions tested for the year 1985: zone 1.5km ($G = 758.13$; $df = 2$; $P < 0.01$), zone 4.5km ($G = 38.35$; $df = 2$; $P < 0.01$), and zone 9.0km ($G = 119.62$; $df = 2$; $P < 0.01$). Similarly, in 2001 there was also a significant difference between observed and expected results for the distance zones: 1.5km ($G = 97.23$; $df = 2$; $P < 0.01$), 4.5km ($G = 46,46$; $df = 2$; $P < 0.01$), and 9.0km ($G = 113.54$; $df = 2$; $P < 0.01$).

In 1985, the approximate relative pasture area occupied was 40% (132,992.4ha), and in 2001, the pasture area occupied was 74% (247,768.5ha). For both years evaluated (1985 and 2001), the pasture ground cover was greater than expected for the distance zone adjacent to the road (distance of up to 1.5km), and less than expected for distances between 1.5 and 4.5km and between 4.5 and 9.0km from the road (Figure 3).

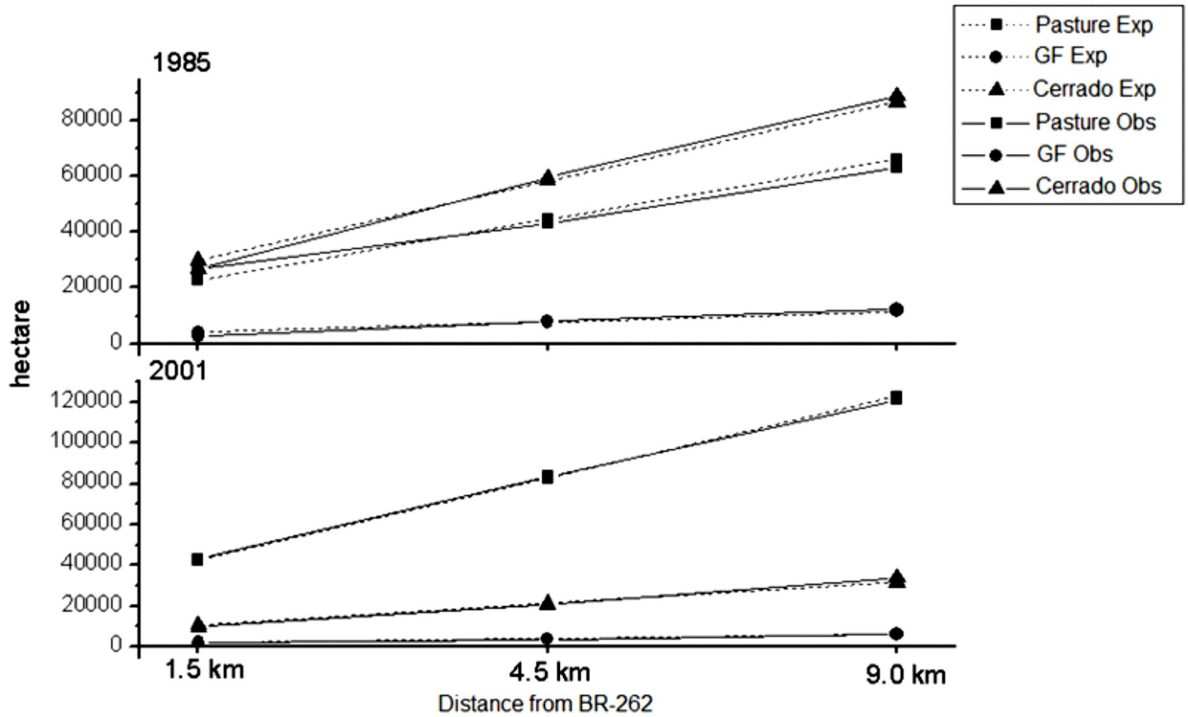


**Figure 3.** Observed (Obs) and expected (Exp) results of hectares occupied by pasture, cerrado, and gallery forest (GF) for the distances from 0 to 1.5km, 1.5 to 4.5km, and from 4.5 to 9.0km of highway BR-262, between Campo Grande to Miranda, for the years 1985 and 2001, with approximately 200km stretch.

The approximate relative area occupied by gallery forest for the year 1985 was 7% (23485.14ha) and 4% in 2001 (12035.25ha). For the years 1985 and 2001 the area occupied by gallery forest was less than expected for the distance zones up to 4.5km, and greater than expected for the 4.5 to 9.0km zone from BR-262.

In 1985, the cerrado ground cover was approximately 52% (175165.8ha) and 19% in 2001 (64205.1ha). For the years 1985 and 2001 there were less cerrado areas adjacent to the highway than expected and more cerrado areas than expected with increasing distance from the highway.

## DISCUSSION

The reversal in the amount of grazing areas and cerrado between 1985 and 2001 showed an evolution in deforestation during the past 16 years, and can lead to important conclusions or predictions concerning the future of the cerrado. According to Machado *et al* (2004), using a conservative deforestation index, there is an 1.1% loss of cerrado per year, and consequently, in 2030 the Cerrado is expected to be vanished. However our data confirms that the evolution of deforestation increases closer to the roads, and based on the 1977 predicted model, the extinction time for the cerrado forest may be reduced. This model was based on the ecological difference between the two states, where the state of Mato Grosso do Sul is a region of grasslands and ideal for cattle ranching and agriculture, and meanwhile, the state of Mato Grosso is covered by forests and less inhabited and explored (Governo do Estado de Mato Grosso do Sul 2009).

Other studies that were conducted concerning the loss of cerrado forest also confirmed that in 1985, 37% of its natural area had been converted into disturbed landscapes because of cattle ranching, the main economic activity in this disturbed landscape (Dias 1994).

In 2002, 55% of the cerrado had been deforested or transformed by human actions (Machado *et al*. 2004). However, our study showed that in 2001 the cerrado had lost much more of its native area in the study region. The fact that the study was restricted to an extension of approximately 200km along a highway can explain the difference found between the studies, and emphasizes that land occupation is facilitated by the road system. The greatest occupation in the cerrado of Mato Grosso do Sul occurred partially because in 1977 the state of Mato Grosso separated from Mato Grosso do Sul. This required better road infrastructure for the new capital of the state, Campo Grande, and other cities; Cuiabá was the previous capital when the two states were united. Until 1985, exploration in this region was less intense, but during the 90's the road system and conditions improved, which caused the state to double in population size (IBGE 2009). As a result of population migration from the other states, there was an intense exploration and rise in cattle ranching establishments (Governo do Estado de Mato Grosso do Sul 2009).

The relation between the area near the road and the level of deforestation is influenced by the easy transportation to the properties. Roads that are paved increase the interest for agriculture and cattle ranching industries because of the easy transportation of products and agents for deforestation (Forman 1995, Nagendra *et al*. 2003, Soares-Filho *et al*. 2004).

In several regions of Brazil, studies also show the tendency of deforestation along the highways. The areas adjacent to the highway are more explored and deforested, while areas that are more distant from the road show a rich forest landscape (Nepstad *et al*. 2001, Fearnside 2007, Freitas *et al*. 2009, Freitas *et al*. 2010).

In general the roads play an important role in accelerating deforestation that starts during the implementation phase and continues to and during the operational phase. The road impacts are irreversible with facilitated settlements, easy access to the surrounding vegetation, introduction of exotic species, and other factors, and consequently cause a loss in biodiversity of the fauna and flora (Fogliati *et al*. 2004, Freitas *et al*. 2010).

The implementation phase of a road generates greater impacts during construction, but the resulting impacts of the operation tend to remain for a long period and causing significant impacts over time (Fogliati *et al*. 2004).

We conclude that the highway in this landscape accelerates environmental degradation in its spatial and temporal context. Deforestation and exploration of the region were significantly influenced by the distance to the road, and the landscape was more conserved at greater distances. Areas near the road are the first to get explored and over time the areas further away can be accessed and eventually become devastated from unplanned exploration.

Despite the fact that this study included only two dates for analysis, the historic occupation of the land encouraged exploration and deforestation for cattle ranching and explains part of the reduction of forested areas and the increase of grazing lands. Monitoring at shorter intervals, and associated with political, economic, social, or even environmental factors can provide a perspective and a more accurate spatial/temporal pattern.

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