EDGE EFFECT ON TREE DIVERSITY, COMPOSITION AND STRUCTURE IN A DECIDUOUS DRY FOREST IN CENTRAL BRAZIL[1]

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ABSTRACT – The effects of edge distance on the structure, composition and diversity of tree community, considering individuals of all size classes, were studied in a well-preserved fragment of deciduous dry forest in northeastern Goiás state, Brazil. Plots were systematically established at six distances (0, 40, 80, 160, 280 and 400 m) from the edge, over 10 orthogonal transects on the forest-pasture edge. It was sampled 602 adult individuals/ha, 8,927 saplings/ha and 54,167 seedlings/ha distributed in 58 species. Although the composition of seedlings and adult individuals varied significantly over the forest-pasture gradient, the variation explained by edge distance was below 4%. Among parameters of community structure and tested diversity indexes, there was significant variation only for diversity of seedlings and height of adult trees among forest-pasture edge distances. The dry forest fragment showed only a slight edge effect on the evaluated tree community parameters. This conclusion contrasts with findings from studies on tropical rain forests which indicate sharp differences between edge and interior tree communities in forest fragments.

Keywords: Biodiversity conservation, Forest fragmentation and Seasonal forest.

EFEITO DE BORDA NA DIVERSIDADE, COMPOSIÇÃO E ESTRUTURA DA COMUNIDADE ARBÓREA EM UMA FLORESTA ESTACIONAL DECIDUAL NO BRASIL CENTRAL

RESUMO – O efeito da distância da borda na estrutura, composição e diversidade da comunidade de árvores, considerando todos os tamanhos de indivíduos, foi estudado em um fragmento bem preservado de Floresta Estacional Decidual no Nordeste do Estado de Goiás, Brasil. Parcelas foram sistematicamente estabelecidas em seis distâncias (0, 40, 80, 160, 280 e 400 m) da borda, ao longo de 10 transecções ortogonais na borda floresta-pastagem. Foram amostrados 602 indivíduos adultos/ha, 8.927 indivíduos juvenis/ha e 54.167 plântulas/ha distribuídas em 58 espécies. Embora a composição de plântulas e adultos tenha variado significativamente ao longo do gradiente floresta-pastagem, a variação explicada pela distância da borda foi abaixo de 4%. Entre as variáveis de estrutura da comunidade e os índices de diversidade testados houve variação significativa apenas na diversidade de plântulas e na altura de adultos entre as distâncias da borda floresta-pastagem. O fragmento de floresta estacional apresentou apenas tênue efeito de borda, considerando-se os parâmetros de comunidade avaliados. Essa conclusão contrasta com resultados encontrados em florestas tropicais úmidas, os quais indicam diferenças abruptas entre a comunidade de árvores da borda e as do interior de fragmentos florestais.

Palavras-chave: Cerrado, Conservação da biodiversidade e Fragmentação de florestas.

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1. INTRODUCTION

Forest fragmentation reduces natural habitats and creates an edge between the original vegetation and the new human-disturbed area (LAURANCE; BIERREGAARD, 1997). Edges change abiotic conditions, which may affect the abundance and distribution of organisms in the remaining native habitat (LAURANCE; BIERREGAARD, 1997; BENITEZ-MALVIDO, 1998; SCARIOT, 1999), even in large fragments (LAURANCE, 2000). Edge effects may restrict the distribution of many organisms to the interior of forest fragments (MURCIA, 1995), and consequently the effective area conserved can be smaller than the present reserve area.

Microclimatic and edaphic conditions at forest edge are generally different from fragment interior (KAPOS, 1989; CAMARGO; KAPOS, 1995; JOSE et al., 1996; WILLIAMS-LINERA, et al., 1998; BURKE; NOL, 1998; RODRIGUES, 1998; DIDHAM and LAWTON, 1999; DAVIES-COLLEY et al., 2000; GEHLHAUSEN et al., 2000; DELGADO et al., 2007, POHLMAN, 2009). These studies indicate that edges have higher values of air and soil temperature, wind speed, vapor pressure deficit, and lower air and soil humidity than forest interior. These altered microclimate conditions affect plant physiology (KAPOS et al., 1993; HERBST et al., 2007), possibly increasing tree mortality (ESSEEN, 1994, D'ANGELO et al., 2004) and causing changes in diversity, composition, structure and dynamics of plant communities at edges of forest fragments.

The processes that rule edge effects in forest fragments are well understood and reasonably consistent throughout the studies carried out in temperate (WHITNEY; RUNKLE, 1981; PALIK; MURPHY, 1990; MATLACK, 1994; HANSSON, 2000) and tropical rain forests (LOVEJOY et al., 1983; WILSON; CROME, 1989; WILLIAMS-LINERA, 1990a; LAURANCE, 1991; LAURANCE et al., 1998; RODRIGUES, 1998; WILLIAMS-LINERA et al., 1998; LAURANCE et al., 2006). However, edge effect trends found elsewhere may not be directly applicable to tropical dry forests.

Tropical dry forests, the most endangered and probably the most fragmented lowland forest in the tropics (JANZEN, 1988; LERDAU et al., 1991; WHITMORE, 1997), have relatively low species diversity (GENTRY, 1995), but have a large life form diversity, which is attributed to the high temporal and spatial heterogeneity in water availability that characterizes these forests (MEDINA, 1995). Similarly to what happens to species diversity, biomass accumulation in dry forests is also limited by water shortage, thus these communities have lower average basal area, height (HOLBROOK et al., 1995) and lower tree density than rain forests (GILLESPIE et al., 2000). Dry tropical forests canopies are more open than the canopy of rain forests and leaf shedding during the dry season increases canopy opening even more (VIEIRA; SCARIOT, 2006). Consequently, it is expected a less contrasting forest-edge microclimate gradient in dry forests than in rain forests, affecting organisms to a smaller extent. Another aspect is that among the reduced species pool in dry forest, it might be less likely to find species that are affected by fragmentation consequences (LAWES et al., 2005). Due to differences in the forest structure (tree height, basal area, density), richness and seasonality (deciduousness) between rain and dry forests, it is anticipated that tropical dry forests may respond differently from rain forests to edge effects.

It was studied the edge effects on the tree community of a deciduous dry forest in Paranã River Valley, central Brazil, to assess whether there are edge effects on structure (basal area, height, diameter and density), species composition and diversity. The findings of this study may contribute to the design and management of reserves in this region and other similar dry forest areas.

2. MATERIAL AND METHODS

2.1. Study area

This study was conducted in a deciduous dry forest in the municipality of São Domingos, in northeastern Goiás State (Figure 1). The forest is located on the Paranã River Basin, a tributary of the Tocantins River.

The climate in the Paranã River Basin is tropical (Aw) with two well-defined seasons. Annual mean temperature is 23^{o}C. The highest temperatures occur in September-October, and in the coldest month, temperatures are above 18^{o}C. Mean annual precipitation is 1300-1500mm, 70% of which falls between October and April, whereas dry conditions during three to four of the remaining months result in water deficit (IBGE, 1995).

The Paranã River Basin is characterized by different kinds of vegetation patchily distributed in the landscape, such as deciduous dry forests on flat terrains, deciduous

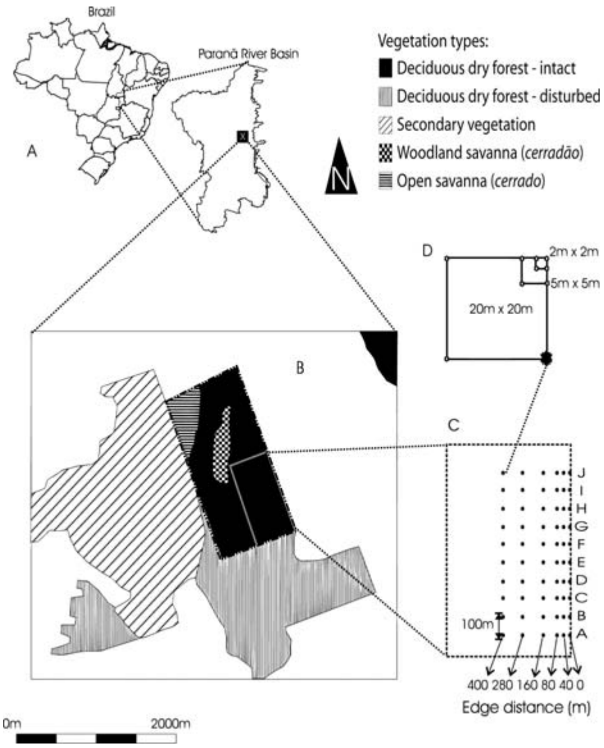

Figure 1 – Study site (A), vegetation types (B) and sampling design (C and D) in the forest fragment in the Paranã River Valley. In each sampling point (C) it was set up plots and subplots to sample the vegetation (D – see methods).

***Figura 1** – Área de estudo (A), tipos de vegetação (B) e desenho amostral (C e D) no fragmento florestal no Vale do Rio Paranã. Em cada ponto de amostragem (C) foram estabelecidas parcelas e subparcelas para amostrar a vegetação (D – veja métodos).*

dry forests on limestone outcrops and on slopes, open savanna (*cerrado*) and woodland savanna (*cerradão*) physiognomies, and riparian forests along the rivers. The vegetation distribution might be determined by soil characteristics and deciduous forests tend to occur on the richer soils, usually Alfisols with high Ca and Mg levels (SCARIOT; SEVILHA, 2000).

The 59,404 square kilometers of the Paranã River Basin was originally covered by forests, savannas or limestone rock outcrops, but today the landscape matrix is dominated by cattle ranches. From 1988 to 1993, over 21% of the original vegetation cover was removed (LUÍZ, 1998). Even more recently, the deforestation has not stopped. Considering a sample area of 181,000 ha of the Paranã River Basin, 67% of the forest cover remaining in 1991 was deforested until 1999 (ANDAHUR, 2001). The remaining forest fragments are used as refuges and foraging sites for cattle and economic valuable timber species are extracted by ranch owners.

The forest fragment studied in this work covered 900 ha. This area can be divided according to vegetation type and human disturbance (Figure 1). It was sampled only a homogeneous portion of the fragment (13^{0}39’26’’S, 46^{0}45’09’’W) characterized by deciduous dry forest that showed no signs of timber exploitation and cattle foraging was the only noticeable human impact. The sampled area abutted disturbed seasonal dry forest and pasture and it was close to a woodland savanna (*cerradão)* patch. The studied forest fragment was located on a flat terrain (<3% inclination) more than 1.5km away from any water course, on Alfisol soil (pH in water = 6.6 ± 0.5, Ca = 9.0 ± 4.2 meq/100g, Mg = 1.7 ± 1.0 meq/100g, average and standard deviation of 83 soil samples taken in the studied fragment and other forests of the same type in the region).

The pasture adjoining the studied forest edge was established about 30 years ago and the original vegetation in the pasture area was seasonal deciduous forest according to satellite images, information from the landowner, remnant tall trees and resprout (VIEIRA et al., 2006). The pasture was planted with *Braquiaria decumbens* Stapf forage grass species and is annually tractor mowed to prevent the grass suppression by the natural regeneration, which is the regular pasture management system in the region (SAMPAIO et al., 2007).

Edge effect may vary depending on several characteristics such as fragment age, size, shape, management of the surrounding matrix and edge aspect (MURCIA, 1995). In the Paranã River Basin, it is impossible to find true replicates for forest-pasture edge with the same age, vegetation type, facing the same direction, with the same conservation and/or management history. It is especially true because the original vegetation was patchily distributed and the management history was highly variable in this region. Since it was unfeasible to account for all landscape heterogeneity the sampling effort was focused to test in detail the edge effect in only one forest fragment, characterizing pseudo-replication (HURLBERT, 1984).

2.2. Sampling

Along the forest-pasture NE edge, 10 400-m perpendicular transects were systematically established, 100 m apart from each other (Figure 1). Along each transect, it was established 20 × 20 m plots at six distances (0, 40, 80, 160, 280 and 400 m, totaling 60 plots with an aggregate area of 2.4 ha) where all adult trees (dbh - diameter at breast height > 5 cm) were sampled. Within each plot, in the lower right corner, it was delimited a 5 × 5 m subplot to sample saplings (dbh < 5 cm and height > 1m) and a 2 × 2 m subplot to sample seedlings (height < 1 m, Figure 1). Height and diameter were recorded for all adults (dbh), saplings (diameter at 30 cm above soil), and seedlings (diameter at 2 cm above soil) individuals. Sampling was conducted from March to May 2000, at the end of the rainy season. Botanical vouchers were collected, species identifications were made by comparison to herbaria specimens and deposited at the Cenargen-Embrapa Herbarium (CEN) in Brasília, Brazil.

2.3. Data analysis

Species richness (S), Shannon-Weiner diversity (H') and Pielou's equitability (J') were estimated for the three size classes in each plot, based on natural logarithms (MARGURRAN, 1988).

Estimates of S, H', J', mean height, diameter and plant density were individually compared by using MANOVA for repeated measures, using the Statistica software package (STATSOFT, INC., 2000). The MANOVA for repeated measures was used as a way to take into account the non-independence among samples (TABACHNICK; FIDELL, 1989; VON ENDE, 1993). In this case, distances to forest-pasture edge was modeled as repeated measures. To assess significance, it was used Pillai's statistics, which are more robust for data that do not completely satisfy the multivariate analysis assumptions (TABACHNICK; FIDELL, 1989).

To compare species composition at each edge distance, mean dissimilarity curves were used for each size class. These curves were estimated by progressively taking sub-samples of increasing size of the total sample (10 plots) for each treatment (distance from the edge). For each sub-sample size (area) the mean dissimilarity was estimated (1 - Sørensen index) using PC-ORD (MCCUNE; MEFFORD, 1997). Pairs of curves were compared for each size classes with Kolmogorov-Smirnov tests (ZAR, 1999).

Proportional similarity index (PS) was used between edge distances for each size class (BROWER et al., 1990) to estimate species composition similarity. To identify changes in species composition and their relationship with edge distance (TER BRAAK, 1987), it was performed a direct gradient analysis through a Canonical Correspondence Analysis (CCA). Significant correlations among plots were estimated with a Monte Carlo test (TER BRAAK, 1987). For these analyses two matrices were used, one of abundance of individual species in the 60 plots and other of plot distances to the nearest forest-pasture edge, treated as an indicator of environmental gradient.

3. RESULTS

A total of the 4,083 individuals from 58 species and 20 plant families were sampled. Leguminosae was the richest family with 21 species. From this total, 1,444 (602/ha) were adult trees from 54 species, 1,339 (8,927/ha) saplings distributed in 47 species and 1,300 (54,167/ha) seedlings belonging to 42 species (Table 1).

3. 1. Diversity

For all size classes, species richness did not change significantly with edge distance (Pillai's = 0.37-0.55, F = 0.59-1.23, P = 0.41-0.71, df = *5, 5,* Table 2). The Shannon-Weiner (H') diversity index for adults and saplings individuals was also not significantly affected by edge distance (Pillai's = 0.33, 0.67, F = 0.49, 2.03, P = 0.23, 0.77, respectively, df = *5, 5,* Table 2). In contrast, there was an increasing trend of seedlings diversity from edge to forest interior (Pillai's = 0.90, F = 8.92, P = 0.016, df = *5, 5,* Figure 2 - A), but Post hoc multiple comparisons did not indicate significant differences among distances.

Equitability (J') did not change with edge distance for any size classes (Pillai's = 0.46-0.63, F = 0.86-1.73, P = 0.28-0.565, df = *5, 5,* Table 2). Likewise, species dissimilarity curves did not differ among edge distances for any size class (Kolmogorov-Smirnov test, seedling: P = 0.31-1.0, sapling: P = 0.66-1.0, adults: P = 0.96-1.0).

3.2. Composition

The vast majority (35 species) of the sampled species was found in all distances to forest-pasture edge (Table 1). The most abundant species for all size classes were found in all distances, only the less abundant species were restricted to certain edge distances.

Table 1 – Species abundance for each size class (adults, saplings and seedlings, see methods for definition) and species presence at six distances (0, 40, 80, 160, 280, 400 meters) to forest-pasture edge in a deciduous dry forest fragment, Goiás State, Brazil. Species presence is shown considering all size classes lumped together. "All" means that the species was found across all sampled distances to the edge.

Tabela 1 – *Abundância para cada uma das espécies de árvore em cada classe de tamanho (adultos, juvenis e plântulas, veja métodos para definição) e a presença das espécies em cada distância (0, 40, 80, 160, 280, 400 metros) da borda pastagem-floresta em um fragmento de floresta estacional decidual, Goiás, Brasil. As classes de tamanho foram agrupadas para mostrar a presença em cada distância da borda. "All" significa que a espécie foi amostrada em todas as distâncias da borda amostradas.*

Family	Species	Adults	Saplings	Seedlings	Presence at edge distances
		Individuals/ha			
Anacardiaceae	*Astronium fraxinifolium* Schott.	7	7	125	All
	Myracrodruon urundeuva Fr. Allem.	38	20	1,667	All
	Schinopsis brasiliensis Engl.	.	40	10,792	All
	Spondias mombin L.	9	7	1,125	All
Apocynaceae	*Aspidosperma pyrifolium* Mart.	19	100	42	All
	Aspidosperma subincanum Mart.	18	207	667	All
	Aspidosperma sp.	5	133	125	All
Bignoniaceae	*Tabebuia impetiginosa* (Mart. ex DC.) Standl.	48	7	417	All
	Tabebuia roseo-alba (Ridley) Sandw.	7	7	.	All
Bombacaceae	*Cavanillesia arborea* K. Schum.	7	.	167	All
	Chorisia pubiflora (St. Hil.) Dawson	3	.	42	All
	Pseudobombax tomentosum (Mart. & Zucc.) A. Robins	9	20	375	All
Boraginaceae	*Cordia trichotoma* (Vell.) Arrab. ex Steud.	.	27	833	All
Celastraceae	*Maytenus floribunda* Reiss.	.	.	42	40
Chrysobalanaceae	*Licania* cf. *arenosa* Taub.	4	47	42	All
Combretaceae	*Combretum duarteanum* Camb.	23	67	42	All
	Combretum sp.	37	827	2,958	All
	Terminalia sp.	1	20	.	160, 400
Flacourtiaceae	*Casearia rupestris* Eichler	10	20	83	All
Leguminosae	*Acacia farnesiana* (L.) Willd.	1	.	42	160
	Acacia glomerosa Benth.	1	147	500	All
	Acacia paniculata Willd.	2	140	375	0, 80, 160, 280, 400
	Acacia polyphylla DC.	3	300	917	All
	Albizia cf. *niopoides* (Spruce ex. Benth.) Burkart.	1	.	.	0
	Amburana cearensis (Fr. Allem.) A. C. Smith.	1	7	.	400
	Anadenanthera peregrina (L.) Speg.	5	53	42	All
	Bauhinia brevipes Vog.	132	973	3,792	All
	Bauhinia cf. *acuruana* Moric.	22	833	.	All
	Copaifera langsdorffii Desf.	1	.	.	40
	Enterolobium contortisiliquum (Vell.) Morong.	1	7	250	0, 40, 80, 160, 280
	Hymenaea courbaril L. var. *stilbocarpa* (Hayne) Y.T.Lee & Langenh.	1	.	83	0, 40, 80
	Lonchocarpus sericeus H. B. & K.	25	100	1,333	All
	Machaerium brasiliense Vog.	21	393	1,000	All
	Machaerium scleroxylon Tul.	7	360	4,875	All
	Machaerium stipitatum (DC.) Vog.	43	3,347	8,333	All
	Machaerium villosum Vog.	5	67	333	All
	Platypodium elegans Vog.	3	13	.	0, 40, 160, 400
	Senna spectabilis (DC.) Irwin & Barn. var. *excelsa* (Schrad.) Irwin & Barn.	4	7	.	0, 40, 80, 160, 280
	Swartzia multijuga Vog.	3	.	83	All
	Sweetia cf. *fruticosa* Spreng.	4	73	417	All
Meliaceae	*Cedrela fissilis* Vell.	5	20	417	All

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Table 1 – Cont.
Tabela 1 – *Cont.*

Moraceae	*Maclura tinctoria* (L.) Don. ex Steud.	1	7	.	0, 400
Myrtaceae	*Eugenia dysenterica* DC.	6	7	125	All
	Eugenia sp.	22	173	1,083	All
	Myrcia tomentosa (Aubl.) DC.	1	20	42	0, 40, 280, 400
	Unknown sp.1	1	7	42	0, 40, 80
Rhamnaceae	*Ziziphus* sp.	1	.	.	400
Rubiaceae	*Alibertia* sp.	.	.	167	40, 160, 280
	Amaioua sp.	3	27	.	0, 40, 160, 400
	Coutarea sp.	1	13	.	0, 280, 400
	Randia armata (Sw.) DC.	5	180	9,667	All
Sapindaceae	*Dilodendron bipinnatum* Radlk.	5	7	42	0, 40, 160, 280, 400
	Talisia esculenta (A. St. Hil.) Radlk.	17	27	83	All
Sapotaceae	*Pouteria gardnerii* (Mart. e Miq.) Baehni.	2	40	.	0, 80, 280, 400
Sterculiaceae	*Guazuma ulmifolia* Lam.	5	.	.	0, 40, 80, 160, 280
	Sterculia striata St. Hil. & Naud.	2	7	.	0, 80, 280, 400
Ulmaceae	*Celtis iguanaea* Sarg.	1	13	583	All
Vochysiaceae	*Callisthene fasciculata* Mart.	1	7	.	280, 400
	Total	**602**	**8927**	**54167**	

Table 2 – Diversity indexes and tree community structure parameters for each size class in plots at different distances from the edge in a deciduous dry forest fragment, Goiás State, Brazil. Mean and standard error (in parenthesis) of diversity indexes (S - richness, H' - Shannon, J' - equitability) and structure parameters (density, diameter, basal area and height).

Tabela 2 – *Índices de diversidade e parâmetros estruturas da comunidade de árvores de cada classe de tamanho em parcelas em diferentes distâncias da borda em um fragmento de Floresta Estacional Decidual no Estado de Goiás, Brasil. Média e erro-padrão (entre parênteses) de índices de diversidade (S - riqueza, H' - Shannon, J' – equabilidade) e parâmetros de estrutura (densidade, diâmetro, área basal e altura).*

		Diversity			Structure			
Size class	Edge Distance(m)	S	H'	J'	Density (individuals/ha)	Diameter (mm)	Basal Area(m^2/ha)	Height (m)
Seedling	0	5.1 (0.7)	1.3 (0.2)	0.3 (0.05)	29,000 (4,761)	3.1 (0.2)	0.30(0.1)	0.4 (0.04)
	40	6.7 (0.5)	1.5 (0.2)	0.5 (0.04)	45,556 (6,200)	2.7 (0.3)	0.49(0.1)	0.3 (0.03)
	80	7.4 (0.8)	1.7 (0.1)	0.4 (0.03)	47,750 (7,231)	2.8 (0.3)	0.36(0.1)	0.3 (0.03)
	160	7.4 (0.7)	1.8 (0.1)	0.5 (0.02)	41,500 (4,717)	3.0 (0.3)	0.40(0.1)	0.3 (0.03)
	280	7.0 (0.8)	1.5 (0.2)	0.4 (0.04)	61,500 (16,284)	3.0 (0.2)	0.69(0.2)	0.4 (0.02)
	400	6.7 (0.5)	1.6 (0.1)	0.4 (0.03)	43,000 (6,189)	3.0 (0.2)	0.40(0.1)	0.3 (0.03)
Sapling	0	8.0 (0.6)	1.6 (0.1)	0.4 (0.03)	10,440 (1,268)	17.4 (1.5)	3.6 (0.3)	2.2 (0.1)
	40	6.9 (1.0)	1.4 (0.1)	0.4 (0.03)	9,280 (1,721)	15.3 (0.9)	2.3 (0.2)	2.2 (0.1)
	80	6.1 (1.0)	1.4 (0.2)	0.4 (0.04)	8,600 (2,037)	17.9 (1.4)	3.0 (0.4)	2.4 (0.1)
	160	6.9 (0.7)	1.6 (0.1)	0.4 (0.02)	7,200 (1,328)	15.7 (1.7)	1.8 (0.4)	2.2 (0.2)
	280	7.7 (0.6)	1.7 (0.1)	0.4 (0.02)	10,560 (2,559)	14.7 (1.4)	2.4 (0.3)	2.1 (0.2)
	400	8.2 (1.0)	1.8 (0.1)	0.5 (0.03)	7,480 (1,029)	14.7 (0.9)	1.9 (0.3)	2.1 (0.1)
Adult	0	13.3 (0.8)	2.3 (0.1)	0.57 (0.02)	733 (57)	154.0(17.7)	28.3 (5.5)	8.4 (0.2)
	40	10.8 (0.7)	2.1 (0.1)	0.53 (0.02)	520 (43)	173.7(12.7)	22.2 (3.5)	10.5 (0.5)
	80	9.5 (0.7)	1.9 (0.1)	0.48 (0.03)	513 (55)	171.2(17.9)	22.8 (5.0)	9.6 (0.5)
	160	11.8 (0.8)	2.2 (0.1)	0.54 (0.02)	603 (44)	171.2(11.6)	26.9 (3.5)	9.7 (0.4)
	280	12.7 (1.0)	2.3 (0.1)	0.57 (0.02)	630 (40)	73.8 (7.2)	36.5 (7.2)	9.8 (0.2)
	400	11.2 (0.8)	2.1 (0.1)	0.52 (0.02)	613 (47)	157.1(10.0)	19.3 (1.7)	9.5 (0.4)

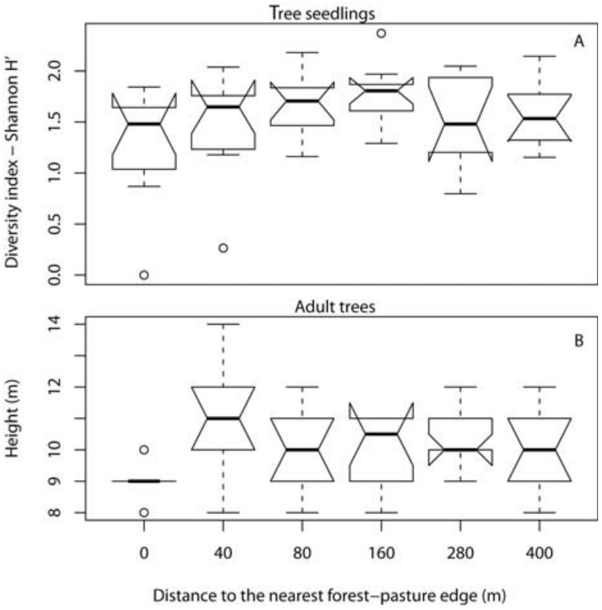

Figure 2 – (A) Shannon diversity index (H') calculated for tree seedlings in plots at each distance from the edge sampled in a deciduous dry forest fragment, Goiás State, Brazil. (B) Mean height of adult trees sampled in plots at different edge distances. Notched box-plots showing quartiles and outliers (circles); overlapping notches indicate no significant diference.

***Figura 2** – (A) Índice de diversidade de Shannon (H') calculado para plântulas em parcelas em cada distância da borda amostrada em um fragmento de Floresta Estacional Decidual no Estado de Goiás, Brasil. (B) Altura de árvores adultas amostradas em parcelas em diferentes distâncias da borda. Gráfico de caixa com cintura indicando os quartis e dados extremos (círculos); cinturas sobrepostas indicam ausência de diferença significativa.*

Based on similarity index, there is no evident trend on species composition related to edge distance for all tree size classes. Similarity was always higher than 50% for saplings and adults. For seedlings, similarity among plots was lower than 50% for nearly half of the compared distance pairs. In general there was more variation in percentage similarity (PS) among edge distances for seedlings (range: 36-65%) than for saplings (60-81%) and adult trees (62-77%). For seedlings, the lowest similarity was between the plots closest to the edge (0 and 40 m), and the highest similarity between the most interior plots (280 and 400 m). Saplings showed a different trend, with the highest similarity between plots closest to the edge (0 and 40 m), and the lowest similarity between the most distant plots (0 and 400 m). Adult trees did not follow any pattern. Species in adult size class were more evenly distributed along the edge-interior gradient of the forest, with 20 (37%) species occurring at all distances compared to 12 (25.5%) at saplings and 10 (23.8%) at seedlings size classes.

According to the Canonical Correspondence Analysis (CCA), tree species composition of the studied forest fragment was significantly related to the distance to forest-pasture edge for seedlings ($F = 1.48$, $P = 0.037$, $df = 1, 57$, $n = 60$, 1,000 permutations, Figure 3) and adults (F=2.1583, $P = 0.001$, $df = 1, 58$, $n = 60$, 1000 permutations, Figure 3). However, only a very small fraction of the variation within the first CCA axis, in both size classes, was explained by the edge distance (2.5% for seedlings, CCA1-eigenvalue = 0.06, and 3.6% for adults, CCA1-eigenvalue = 0.06). In fact, for seedlings, the CCA was only significant after excluding an outlier plot that contained an abnormally high (>100 times higher) abundance of *Schinopsis brasiliensis*, all concentrated under the mother tree abutting to this plot. For adults, all the plots with more than two units of variation in the first CCA axis are only separated from the others due to a higher abundance of a single species, *Combretum duarteanum*, in these plots. For both seedlings and adults, the majority of plots across distances are grouped together and enclosed in between one unit of variation around zero in the first CCA axis (Figure3). The most distinct plots for both seedlings and adult communities are mainly in the extremes of the edge distance gradient (0 and 400 meters). Finally, for saplings, species composition was unrelated to edge distance ($F = 1.39$, $P = 0.068$, $df = 1, 58$, $n = 60$, 1,000 permutations).

3.3. Structure

Despite the lower number of seedlings and adult individuals in plots located closest to the edge (0 m plots), mean density did not significantly change with edge distance for any size classes (Pillai's = 0.37-0.61, F = 0.57-1.54, P = 0.32-0.72, $df = 5, 5$, $n = 10$, Table 2). For all size classes there were no significant changes (Table 2) in mean diameter (Pillai's = 0.22-0.63, F = 0.28-1.68, P = 0.29-0.91, $df = 5, 5$, $n = 10$) and basal area with edge distance (Pillai's = 0.33-0.67, F = 0.49-2.03, P = 0.23-0.77, $df = 5, 5$, $n = 10$).

Mean height of seedlings and saplings individuals did not change with edge distance (Pillai's = 0.28-0.64, F = 0.38-1.81, P = 0.26-0.84, $df = 5, 5$, $n = 10$). Although

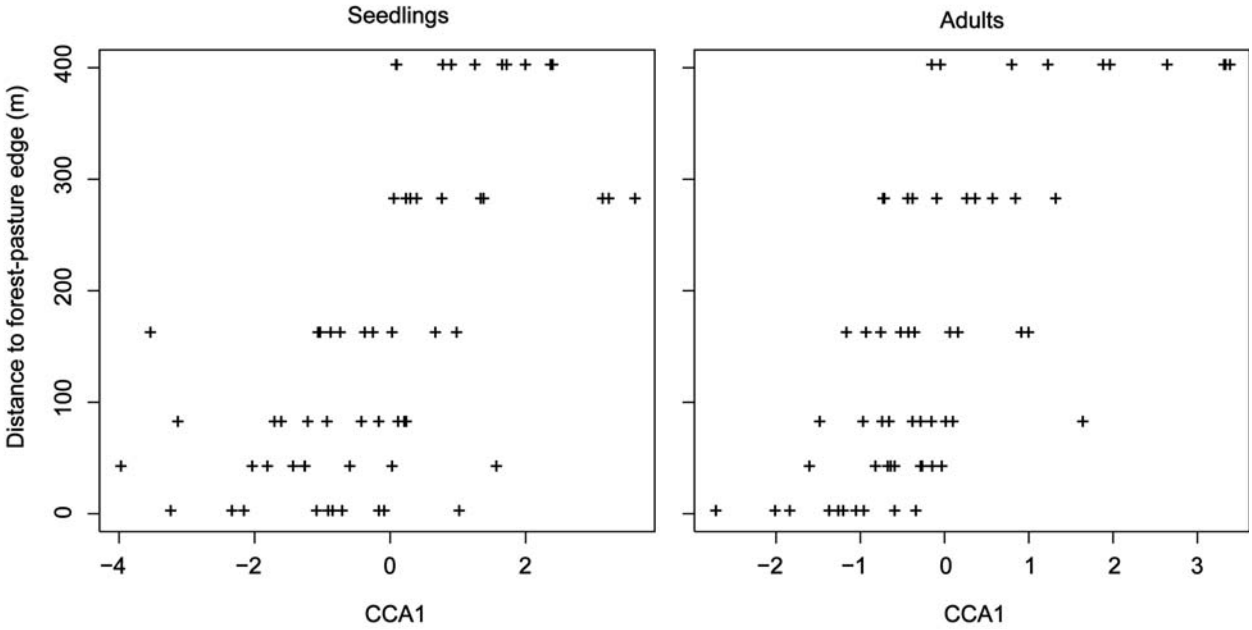

Figure 3 – Canonical Correspondence Analysis (CCA) of seedlings and adult trees in a deciduous dry forest, Goiás State, Brazil. The analysis was based on abundance of individuals per species in each sampled plot (*n* = 60) related to the plot distance to the nearest forest-pasture edge. Each cross represents a plot.
Figura 3 *– Análise contingenciada de correspondência (CCA) de plântulas e árvores adultas em uma Floresta Estacional Decidual no Estado de Goiás, Brasil. A análise foi baseada na abundância de indivíduos por espécies em cada parcela amostrada (n = 60), relacionada com a distância de cada parcela na borda floresta-pastagem mais próxima. Cada cruz representa uma parcela.*

adult tree height varied (Pillai's = 0.90, $F = 8.80$, $P = 0.01$, $df = 5, 5$, $n = 10$) (Table 2, Figure 2 - B) with the plots closest to the edge (0 m) showing lower mean height than the plots at 40 meters (Bonferroni Post hoc test, $P = 0.032$).

4. DISCUSSION

The assumptions made based on results from this work must be carefully considered because only one forest-pasture edge was sampled. Edge effect may vary depending on several factors such as fragment age, size, shape, matrix management and edge orientation which were not considered by the present study (MURCIA, 1995). Nonetheless, the studied fragment has structure and species composition similar to other seasonal deciduous forests in the region (SCARIOT; SEVILHA, 2000), indicating that the inconspicuous edge effect found in the studied area might occur in other areas with the same vegetation type in the Paranã River Valley, Central Brazil.

The absence of edge effect in forest fragments has been found in recent studies. Even in the Amazon rain forest, where edge effects were considered formerly as one of the most extensive impacts for biodiversity conservation of forest fragments (LAURANCE, 2000; LAURANCE et al., 2006). PHILLIPS et al. (2006) reported the absence of edge effects fragments in rain forests from the Southwestern Peruvian Amazon. Another example shows that neither richness nor abundance of woody seedlings was affected by edge effect in Afromontane forests in South Africa (LAWES et al., 2005). Absence of edge effects was also found in a temperate forest, where tree growth is more related to soil and topography characteristics than to edge effect (MCDONALD; URBAN, 2004).

In this work, diversity of tree species in adult and sapling size classes was not affected by edge effect. This result contradicts most studies in tropical and temperate forests on edge effects that found less species in edges compared to forest interior (BURKE; NOL,

1998; RODRIGUES, 1998; GOLDBLUM; BEATTY, 1999; GEHLHAUSEN et al., 2000; OLIVEIRA FILHO et al., 2004). The only noticeable edge effect in the studied forest fragment in terms of species diversity was found in the seedlings class. This effect was a slight reduction on seedlings diversity with the edge proximity. Seedling can be the first size class to be affected by edge effect, because they are the life stage more sensitive to the environment or biotic interactions (SAUNDERS et al., 1991; RODRIGUES, 1998). High predation or harsh environmental conditions in the edge may be restricting the recruitment of some species in detriment of others (HOLL; LULOW, 1997; WONG et al., 1998; SONG; HANNON, 1999; CADENASSO; PICKETT, 2000; NAVA-CRUZ, 2007). Nonetheless, community structure of seedlings is very dynamic, after the fruiting season that happens during the beginning of the rainy season in dry forest regions (VIEIRA; SCARIOT, 2006) the forest floor tends to be covered by seedlings. Then, by the end of the rainy season and beginning of the next dry season, most of those seedlings die (CABIN, 2002). Therefore, without following seedling dynamic is hard to make statements about edge effect on seedlings.

The species composition of trees in the adult and seedling size classes formed a gradient following the distance to forest-pasture edge, but there were no distinct communities occurring in forest interior or in edge habitat. A continuous variation in plant species composition associated with edge effect was also found in an *Araucaria* Forest in southern Brazil, possibly due to edge colonization by light demanding species (FONTOURA et al., 2006). Even though, in this study, the ordination axis for seedling and adult size classes were correlated to edge distance, this was a weak pattern because only a small part of the species composition variation was explained by the ordination axis. The lack of strong correlation of species composition with edge effect may not be an unusual pattern in Brazilian dry forests, Oliveira-Filho et al. (1997) reported an absence of edge effect in the species composition of adult trees found in a semi deciduous forest fragment in southeastern Brazil. Furthermore, in a tropical forest in Uganda, tree species composition did not vary with the edge-interior gradient, even though the analysis of each species separately showed significant correlations for most species with distance to forest-edge, considering one or more of the following parameters: density, relative abundance, relative frequency, relative dominance, importance value index and basal area (OLUPOT, 2009). Thus, edge effects may be impacting species individually in positive and negative manners which may be compensatory and prevent the detection of effects on the community level.

The only identifiable pattern of species composition in the studied fragment was a slightly distinct tree community in the transition of the deciduous dry forest and the woodland savanna patch (Figure 1). This pattern was found only for the individuals in the adult size class. The ordination analysis separated the plots in the dry forest-woodland savanna transition due to the much higher density of *Combretum duarteanum*. This pattern is probably not related to the forest-pasture edge effect because: (1) *C. duarteanum* populations are denser in the woodland savanna (A.B. Sampaio, personal observation) and (2) because other plots far from the savanna patch but at same forest-pasture edge distance were not grouped with the savanna-transition plots in the ordination analysis.

The mean height of trees in adult class was smaller in the edge compared to the interior plots. This pattern also found elsewhere might occur due to high mortality of tall trees in the edge during the first years after edge creation (ESSEEN, 1994; D'ANGELO et al., 2004). This may increase recruitment of new trees and subsequently reduce average tree height in the forest fragment edge. However, in the studied forest fragment this increased recruitment just after edge creation was probably not high enough to increase the density of trees. In other situations, this edge effect is more striking. CASENAVE et al. (1995) found both lower tree height and higher density at the edge in a semi-arid forest in the Argentinean Chaco and the same was reported in a temperate deciduous forest in Canada (BURKE; NOL, 1998). Also, Laurel and Pine forests in Tenerife, Canary Islands, had smaller trees in the edge compared to the forest interior (DELGADO et al., 2007).

Failure to detect evident edge effect on diversity and structure of tree community may result from several factors, such as: (1) Sampling scale - biotic changes might occur only within the first few meters from the edge, and not be detected due to larger scale plots (DIDHAM; LAWTON, 1999); (2) Edge dynamics – as tree community parameters vary over time, edge effects might disappear over the years (MATLACK, 1994;

WILLIAMS-LINERA et al., 1998; LAWES et al., 2005) or, alternatively, a few years or decades might not be not enough time for fragmentation effects to be noticeable (SCARIOT, 1999); (3) Edges interaction – the effect of a single edge may not be strong enough to be detected but in small fragments where several edges interact, their combined effect may be significant (MALCOLM, 1994; DIDHAM; LAWTON, 1999); (4) Cattle browsing – cattle foraging inside forest fragments may interact with edge effects confounding the results (PALIK; MURPHY, 1990).

Additionally, dry forests might actually be less vulnerable to edge effect than rain forests due to the fact that the species are more adapted to harsher environmental conditions and drought desiccation (VIEIRA; SCARIOT, 2006). In this context, edges become not as different from the forest interior as in tropical rain forests. One factor that might contribute to the resistance of dry forest species to disturbances, including edge effects, is the capacity of fast growth due to the nutrient rich soils where they usually occur (LAWES et al., 2005; VIEIRA; SCARIOT, 2006). The fast growth of tree species in Southwestern Amazon forests in rich soils was considered responsible for forest resistance to disturbance, such as gap creation, and explains the absence of edge effect in those forest fragments (PHILLIPS et al., 2006). Species-poor forests, such as dry forests (GENTRY, 1995), may have less chance to show edge effect on species richness (LAWES et al., 2005), i.e. less species or less rare species means lower risk to edge effects. Although the results from this work are in accordance with the hypothesis that edge effects are not so important in dry forests, this hypothesis which needs further specific studies to be confirmed was not tested in this work.

5. CONCLUSION

Most studies conducted in temperate and tropical rain forests detected evident edge effects (e.g. WILLIAMS-LINERA, 1990; LAURANCE et al., 1998; GEHLHAUSEN et al., 2000), although results do not elucidate a common pattern for all parameters studied (MURCIA, 1995) and there are even a few examples of less pronounced effects in these forests (MCDONALD; URBAN, 2004; LAWES et al., 2005; PHILLIPS et al. 2006). For dry forests, there are not enough studies on fragmentation to draw general conclusions about edge effect, but it is reasonable to expect differences to what was found so far for wetter forests. The present study contributes to the forest fragmentation knowledge by adding one more evidence to the fact that there are types of vegetation and conditions where edge effects may be negligible and that in these situations, management efforts should focus on restoration and deforestation reduction.

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