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Dynamics of the woody vegetation of two areas of Cerrado *sensu stricto* located on different substrates

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Abstract

Differences in substrates can provoke distinct responses in the dynamics of a plant community. We compared changes the floristic, structural and dynamic parameters of the woody vegetation between burned sites dominated by *cerrado típico* (CT) and *cerrado rupestre* (CR), which is characterized by the presence of rocky outcrops, over time. We set up 10 plots (20 m × 50 m) at each site. All individuals (diameter of ≥ 3 cm at 30 cm height above the ground) were identified in the two censuses (2009 and 2012) and measured (stem diameter), after an accidental fire in 2008. Changes in floristic parameters between the CT and CR were not significant. However, we found significant differences ($p < 0.05$) in structural and dynamic parameters, such as density (CT = 1,523; CR = 2,171 ind.ha⁻¹), basal area (CT = 8.70; CR = 13.00 m².ha⁻¹), recruitment rates (CT = 24.35; CR = 15.14% year⁻¹; $p = 0.01$), gain (CT = 8.58; CR = 3.58% year⁻¹), and the loss rates of basal area (CT = 3.88; CR = 2.45% year⁻¹). These differences emphasize the need for a differential evaluation of these sites for the development of effective conservation strategies.

Key words: changes, density, floristic, mortality, recruitment.

Resumo

A diferença de substrato pode causar respostas distintas sobre a dinâmica da comunidade vegetal. O objetivo deste trabalho foi comparar os parâmetros florístico, estruturais e de dinâmica da vegetação entre áreas queimadas de cerrado típico (CT) e cerrado rupestre (CR) (presença de afloramentos rochosos) ao longo do tempo. Foram estabelecidas 10 parcelas (20 m × 50 m) em cada local. Todos os indivíduos com diâmetro ≥ 3 cm a 30 cm de altura acima do solo foram identificados e mediu-se o diâmetro do caule tanto em 2009 quanto em 2012, depois de uma queima acidental em 2008. As mudanças nos parâmetros florísticos não foram significativas entre o CT e CR. Entretanto, foram encontradas diferenças ($p < 0,05$) principalmente com relação aos parâmetros estruturais e de dinâmica, como densidade (CT = 1.523; CR = 2.171 ind.ha⁻¹), área basal (CT = 8,70; CR = 13,00 m².ha⁻¹), taxa de recrutamento (CT = 24,35; CR = 15,14% ano⁻¹; $p = 0,01$), ganho (CT = 8,58; CR = 3,58% ano⁻¹; $p = 0,02$) e perda em área basal (CT = 3,88; CR = 2,45% ano⁻¹). Essas diferenças enfatizam a necessidade de avaliar de forma diferenciada essas fisionomias para criação de futuras estratégias de conservação.

Palavras-chave: mudanças, densidade, florística, mortalidade, recrutamento.

Introduction

The vegetation of the Cerrado biome occurs heterogeneously in space, forming a distinct mosaic (Ribeiro & Walter 2008). In the classification of Ribeiro & Walter (2008), the Cerrado *sensu*

stricto is a savanna formation of the Cerrado biome characterized by a sparse tree-shrub stratum with tortuous trunks, irregular branches, and a continuous grassy stratum. It is divided into four physiognomies: *cerrado denso* (dense cerrado),

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cerrado típico (typical cerrado), *cerrado ralo* (sparse cerrado) and *cerrado rupestre* (rocky cerrado). These physiognomies are distinguished mainly by the type of soil and tree density, height, and cover.

The *cerrado rupestre* is different from the other three physiognomies because it occurs on soils with rocky outcrops and a reduced content of organic matter, typically on steep and hilly terrain, dominated by litholic neosols (Reatto *et al.* 2008). By contrast, the *cerrado típico* is intermediate between the *cerrado denso* and *cerrado ralo*, in terms of its tree density (Ribeiro & Walter 2008), and it is found typically on deep, dystrophic and well-drained latosol type soils, on flat to slightly undulating terrain (Reatto *et al.* 2008).

The rocky outcrops of the *cerrado rupestre* act as barriers to the root systems of the woody and shrubby strata, which are forced to grow between the rock crevices and may only increase in density where enough substrate is available (Felfili & Fagg 2007; Ribeiro & Walter 2008). However, the presumed physical limitations on the development of *cerrado rupestre* plants has not been confirmed by the recent studies that have compared the floristic and structural parameters of the woody communities of adjacent *cerrado rupestre* and *cerrado típico* communities, indicating that this vegetation is adapted to the conditions prevailing in these environments (Pinto *et al.* 2009; Gomes *et al.* 2011). Despite the floristic and structural similarities between *cerrado rupestre* and *cerrado típico* sites (Pinto *et al.* 2009), it is still unclear whether changes in the composition of the vegetation and its structure and dynamics, are similar between these physiognomies over time.

Studies of vegetation dynamics are crucial to the understanding of the intrinsic ecological and temporal processes of plant communities, such as mortality and recruitment (Corrêa & Van Den Berg 2002; Henriques & Hay 2002), in particular when these communities have suffered some type of disturbance, such as the fire. In the Cerrado biome, natural or anthropogenic fires are commonly observed during the dry season (Klink & Machado 2005; Miranda *et al.* 2010), and the data generated by these studies may contribute to the development of conservation and management strategies (Libano & Felfili 2006; Pivello 2011). The aim of the present study was to compare changes in the floristic, structural and dynamic parameters of the woody vegetation between burned sites dominated by typical cerrado and rocky cerrado over time (2009–2012).

Material and Methods

Study area

We conducted this study in the Bacaba Municipal Park (14°41'S, 52°20'W) in the municipality of Nova Xavantina, Mato Grosso, Brazil. The region's climate is of the *Aw* type in Köppen's classification (Peel *et al.* 2007), with two well-defined seasons: a dry and cool season (April to September) and a hot and rainy season, between October and March (Silva *et al.* 2008). Mean annual rainfall is 1,520 mm and average temperature is nearly 24.8°C (Marimon-Junior & Haridasan 2005). The park comprises approximately 500 ha, dominated by *cerrado sensu stricto*, composed of the *cerrado rupestre* and *cerrado típico* physiognomies (Gomes *et al.* 2011).

We selected two adjacent sites, which had been completely burned by an accidental fire in September 2008. Both sites had previously been protected from fire for over 20 years. As the fire was unplanned, it was not possible to measure vegetation parameters before the event. One site is an area of *cerrado típico* (CT) located on dystrophic, allic and acidic cambisols (Marimon-Junior & Haridasan 2005) on flat terrain at altitudes of between 327 m and 331 m. The second site is an area of *cerrado rupestre* (CR) established on quartzitic lithic neosol (Marimon-Junior & Haridasan 2005) on steeply-sloping terrain at altitudes ranging from 339 m to 406 m. We measured the vegetation in January 2009 (four months post-fire) and in January 2012 (40 months post-fire).

Data collection

We used the permanent plot method of Philip (1994), based on 10 plots of 20 m × 50 m at each site (CR and CT), with plots being at least 50 m apart, and a total area of one hectare per site. The CR plots were arranged perpendicularly to the predominant slope of the outcrop to control for possible variations in the topographic gradient, as suggested by Oliveira-Filho (1994). We measured the stem diameter of all live and dead trees with a diameter ≥ 3 cm at 30 cm height above ground level, following Gomes *et al.* (2014). For taxonomic identification, we compared the botanical material collected in the field with voucher specimens in the collection of the NX Herbarium at Mato Grosso State University in Nova Xavantina. We used the Angiosperm Phylogeny Group's (APG III) (2009) botanical classification system and the taxon names were updated using the "International Plant Names

Table 1 – Parameters used to compare the post-fire dynamics between the *cerrado típico* (CT) and *cerrado rupestre* (CR) in of the Bacaba Municipal Park, Nova Xavantina, Mato Grosso, Brazil. *t* = time elapsed between surveys; N_0 = initial number of individuals; N_t = final number of individuals; N_d = number of dead individuals; N_r = number of recruits; AB_0 = initial basal area; AB_t = final basal area; AB_d = basal area of d dead individuals; AB_r = basal area of recruits; AB_d = decrease in basal area; AB_g = increase in basal area; Ln = natural logarithm. Adapted with permission from Gomes *et al.* (2014).

Dynamics parameters	Equation	Author
Number of Individuals (N)		
Average annual mortality rate (% year ⁻¹)	$Mo = \{1 - [(N_0 - N_d) / N_0]^{1/t}\} \times 100$	Sheil <i>et al.</i> (1995; 2000)
Average annual recruitment rate (% year ⁻¹)	$Re = [1 - (1 - N_r / N_t)^{1/t}] \times 100$	Sheil <i>et al.</i> (1995; 2000)
Reposition time (turnover) (years)	$Rep_N = ((T_{1/2N} + T_{2N}) / 2)$	Korning & Balslev (1994)
Half-life time (years)	$T_{1/2N} = Ln_{(1/2)} / Ln([(N_0 - N_d) / N_0]^{1/t})$	Lieberman <i>et al.</i> (1985)
Doubling time (years)	$T_{2N} = Ln_{(2)} / Ln([(N_0 + N_r) / N_0]^{1/t})$	Lieberman <i>et al.</i> (1985)
Stability time (years)	$E_N = (T_{1/2N} - T_{2N})$	Korning & Balslev (1994)
Net change rate (% year ⁻¹)	$Ch_N = [(N_t / N_0)^{1/t} - 1] \times 100$	Korning & Balslev (1994)
Basal Area (AB)		
Average annual loss rate (% year ⁻¹)	$Pe = \{1 - [(AB_0 - AB_d) / AB_0]^{1/t}\} \times 100$	Guimarães <i>et al.</i> (2008)
Average annual rate of gain rate (% year ⁻¹)	$G = \{1 - [1 - (AB_t + AB_g) / AB_0]^{1/t}\} \times 100$	Guimarães <i>et al.</i> (2008)
Reposition time (turnover) (years)	$Rep_{AB} = (T_{1/2AB} + T_{2AB}) / 2$	Korning & Balslev (1994)
Half-life time (years)	$T_{1/2AB} = Ln_{(1/2)} / Ln([(AB_0 - AB_d) / AB_0]^{1/t})$	Lieberman <i>et al.</i> (1985)
Doubling time (years)	$T_{2AB} = Ln_{(2)} / Ln([(AB_0 + AB_g) / AB_0]^{1/t})$	Lieberman <i>et al.</i> (1985)
Stability time (years)	$E_{AB} = (T_{1/2AB} - T_{2AB})$	Korning & Balslev (1994)
Net change rate (% year ⁻¹)	$Ch_{AB} = [(AB_t / AB_0)^{1/t} - 1] \times 100$	Korning & Balslev (1994)

Index-2012” (<<http://www.ipni.org>>). The fertile botanical material collected in the field was deposited at the NX Herbarium.

Floristic parameters

Species richness at each site (CT and CR) in both censuses (2009 and 2012) was estimated using the matrix of the density of individuals per plot through a Detrended Correspondence Analysis (DCA), which spatializes the species data according to the abundance of species, in order to best visualize the groupings (Kent & Coker 1992; McCune & Grace 2002).

Structural parameters

We calculated the density (number of individuals per hectare) and basal area (volume of stems per hectare) of individuals at both sites using the Mata Nativa 2.0 software (Cientec 2006). The *t* test for independent samples was used to compare the density and basal area between sites in each census, and the paired *t* test was used to compare

density and basal area between censuses at each site (Zar 2010).

Dynamic parameters

For each census, we calculated the dynamic parameters of the vegetation, related to the number of individuals and their basal area (Tab. 1), including the mean annual mortality rate (annual percentage of dead individuals) and recruitment rate (annual percentage of individuals who have reached minimum inclusion diameter, *i.e.*, ≥ 3 cm at 30 cm height above ground level), the replacement time or turnover rate (number of years needed to reestablish the number of individuals or basal area initial), half-life (the number of years needed for a community to reduce by 50% the number of individuals or the basal area), and doubling time (the amount of years it takes to double the number of individuals or basal area of a community), stability time (number of years needed to stabilize the number of individuals or basal area), and the net rate of change (annual

percentage change in number of individuals or basal area).

In order to correct the bias related to the variation in the interval between censuses, we applied a correction factor (Lewis *et al.* 2004), based on the formula $\lambda_{corr} = \lambda \times t^{0.08}$, where: λ is the rate and t is the interval in years. We also calculated the number of individuals of each diameter class that persisted, died, were recruited and either immigrated or emigrated (Lieberman *et al.* 1985), as proposed by Spiegel (1976). We applied the t test for independent samples to compare these parameters between sites (Hollander & Wolfe 1973). For each site, we tested the association between diameter classes and annual rates of mortality and recruitment, and loss and gain (basal area) using Spearman's correlation, R_s (Zar 2010).

All these analyses were run in the appropriate package of the R statistical software (R Development Core Team 2009), considering a 5% level of significance. Homogeneity of variances was assessed by Levene's test, and the data were log-transformed when homoscedasticity was not found (Zar 2010).

Results

Floristic parameters

The CT plots were well separated from the CR plots in the ordination analysis (DCA) (Fig. 1). Species richness in the CT increased 7.3% from 89 to 96 between the 2009 and 2012 censuses. In the CR, during the same period, species richness increased 2.5% from 78 to 80 (Tabs. 2; 3).

Structural parameters

In 2009, the CR presented 648 ind.ha⁻¹ more than CT, although densities were similar at the two sites in 2012. The density of individuals in the CT varied between censuses (2009 and 2012), increasing by 46.1% (Tabs. 2; 3). Density in the CR also increased between censuses (2009 and 2012), by 26.8%. Basal area was greater in the CR in both years (Tab. 2), with an excess of 4.30 m².ha⁻¹ being recorded in 2009, and 3.65 m².ha⁻¹ in 2012 in comparison with the CT. Total basal area at each site (CT and CR) also varied between censuses (2009 and 2012), with basal area increasing by 24.5% (2.82 m².ha⁻¹) in the CT and by 14.3% (2.17 m².ha⁻¹) in the CR (Tabs. 2; 3). Density increased at both sites owing to the fact that the density of some species more than doubled between censuses. These species were *Kielmeyera rubriflora* in the CR

and CT and *Erythroxylum suberosum*, *Heteropterys byrsonimifolia* and *Myrcia lanuginosa* in the CT. Furthermore, increases in density and basal area occurred in smaller diameter classes in both the CT (Figs. 2c,d) and CR (Figs. 3c,d).

Dynamic parameters

There was no difference between sites in mean annual mortality rates, although the annual recruitment rate was higher in the CT in comparison with the CR. Mean annual recruitment was higher than mortality, resulting in an increase in the density of individuals at both sites over the course of the study period (Tabs. 2; 4). The mean annual rate of loss of basal area was lower than that of the gain in basal area at both sites, although rates of basal area loss and gain were both greater in the CT compared with the CR.

Half-life times were higher than the doubling times (individuals and basal area) recorded at both sites, and the doubling time was higher in the CR than in the CT in both cases. Even so, half-life and stability times were similar at both sites, not only in terms of the number of individuals but also basal area (Tab. 4). In addition, the net rates of change in the number of individuals and basal area were positive at both sites, while only the basal area turnover rates were lower in the CT compared to the CR (Tab. 4).

Higher mortality rates were recorded in the smaller diameter classes in both the CT and CR

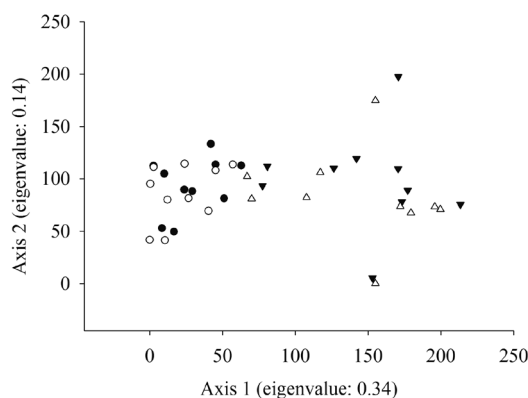


Figure 1 – Arrangement of the DCA (Detrended Correspondence Analysis) ordination axes of the woody vegetation plots sampled in the *cerrado típico* in 2009 (▼) and 2012 (△) and the *cerrado rupestre* in 2009 (●) and 2012 (○) in Bacaba Municipal Park, Nova Xavantina, Mato Grosso, Brazil.

Table 2 – Families, species, and density of woody individuals recorded in the *cerrado típico* (CT) and *cerrado rupestre* (CR) in Bacaba Municipal Park, Nova Xavantina, Mato Grosso, Brazil. The species are ordered by the density found in the CR in 2009. * = species that increased by at least 50% between censuses in the number of individuals.

Species	Family	CT		CR	
		2009	2012	2009	2012
<i>Qualea parviflora</i> Mart.	Vochysiaceae	220	298	275	313
<i>Erythroxylum suberosum</i> A.St.-Hil.	Erythroxylaceae	60	150*	240	270
<i>Kielmeyera rubriflora</i> Cambess.	Clusiaceae	45	121*	148	403*
<i>Vatairea macrocarpa</i> (Benth.) Ducke	Fabaceae	15	36	126	231
<i>Anacardium occidentale</i> L.	Anacardiaceae	37	47	91	97
<i>Heteropterys byrsonimifolia</i> A.Juss.	Malpighiaceae	24	105*	84	141
<i>Eugenia aurata</i> O.Berg	Myrtaceae	30	30	77	75
<i>Syagrus flexuosa</i> (Mart.) Becc.	Arecaceae	69	137	76	95
<i>Pseudobombax longiflorum</i> (Mart. & Zucc.) A.Robyns	Malvaceae	24	45	75	148
<i>Dalbergia miscolobium</i> Benth.	Fabaceae	2	4	59	87
<i>Tachigali aurea</i> Tul.	Fabaceae	22	31	59	63
<i>Davilla elliptica</i> A.St.-Hil.	Dilleniaceae	127	145	56	51
<i>Lafoensia pacari</i> A.St.-Hil.	Lythraceae	13	75	45	66
<i>Dipteryx alata</i> Vogel	Fabaceae	15	30	44	50
<i>Leptolobium dasycarpum</i> Vogel	Fabaceae	4	7	41	43
<i>Qualea multiflora</i> Mart.	Vochysiaceae	26	39	41	55
<i>Hymenaea stigonocarpa</i> Mart. ex Hayne	Fabaceae	8	13	40	55
<i>Myrcia lanuginosa</i> O.Berg	Myrtaceae	94	327*	36	62
<i>Magonia pubescens</i> A.St.-Hil.	Sapindaceae	8	11	35	33
<i>Erythroxylum tortuosum</i> Mart.	Erythroxylaceae	12	16	32	45
<i>Aspidosperma macrocarpon</i> Mart.	Apocynaceae	2	2	29	25
<i>Pterodon pubescens</i> (Benth.) Benth.	Fabaceae	1	2	28	38
<i>Aspidosperma tomentosum</i> Mart.	Apocynaceae	61	70	27	25
<i>Arrabidaea cinnamomea</i> (A. DC.) Sandwith	Bignoniaceae	-	-	24	27
<i>Vellozia squamata</i> Pohl	Velloziaceae	4	4	22	31
<i>Tocoyena formosa</i> (Cham. & Schltdl.) K.Schum.	Rubiaceae	10	23	21	28
<i>Mezilaurus crassiramea</i> (Meisn.) Taub. ex Mez	Lauraceae	1	1	18	17
<i>Byrsonima coccolobifolia</i> Kunth	Malpighiaceae	42	51	17	15
<i>Plathymenia reticulata</i> Benth.	Fabaceae	6	10	17	26
<i>Eriotheca gracilipes</i> (K.Schum.) A.Robyns	Malvaceae	17	41	16	22
<i>Qualea grandiflora</i> Mart.	Vochysiaceae	22	27	16	21
<i>Byrsonima pachyphylla</i> A.Juss.	Malpighiaceae	81	106	15	14
<i>Cordia sessilis</i> (Vell.) Kuntze	Rubiaceae	-	-	15	16
<i>Guapira graciliflora</i> (Mart. ex Schmidt) Lundell	Nyctaginaceae	3	12	15	13
<i>Agonandra brasiliensis</i> Miers ex Benth. & Hook.f.	Opiliaceae	1	3	14	16

Species	Family	CT		CR	
		2009	2012	2009	2012
<i>Ouratea spectabilis</i> (Mart.) Engl.	Ochnaceae	24	42	13	9
<i>Bowdichia virgilioides</i> Kunth	Fabaceae	7	10	12	11
<i>Kielmeyera coriacea</i> Mart. & Zucc.	Clusiaceae	6	9	12	21
<i>Tabebuia aurea</i> (Silva Manso) Benth. & Hook.f. ex S.Moore	Bignoniaceae	10	13	12	12
<i>Mouriri elliptica</i> Mart.	Melastomataceae	13	15	11	10
<i>Salvertia convallariodora</i> A.St.-Hil.	Vochysiaceae	41	46	9	10
<i>Eugenia glazioviana</i> Kiaersk.	Myrtaceae	-	-	8	7
<i>Andira cujabensis</i> Benth.	Fabaceae	3	5	7	7
<i>Astronium fraxinifolium</i> Schott	Anacardiaceae	12	30	7	8
<i>Eugenia gemmiflora</i> O.Berg	Myrtaceae	3	3	6	9
<i>Jacaranda brasiliiana</i> (Lam.) Pers.	Bignoniaceae	-	-	6	6
<i>Mimosa laticifera</i> Rizzini & A.Mattos	Fabaceae	11	44	6	13
<i>Neea theifera</i> Oerst.	Nyctaginaceae	-	-	6	6
<i>Pouteria gardneri</i> (Mart. & Miq.) Baehni	Sapotaceae	-	-	6	6
<i>Curatella americana</i> L.	Dilleniaceae	35	33	5	5
<i>Luetzelburgia praecox</i> (Harms) Harms	Fabaceae	7	7	5	5
<i>Rourea induta</i> Planch.	Connaraceae	1	7	5	7
<i>Syagrus comosa</i> (Mart.) Mart.	Arecaceae	8	49	5	20
<i>Diplopterys pubipetala</i> (A. Juss.) W.R. Anderson & C. Davis	Malpighiaceae	2	4	4	5
<i>Connarus suberosus</i> Planch.	Connaraceae	6	17	4	4
<i>Erythroxylum engleri</i> O.E.Schulz	Erythroxylaceae	4	14	4	5
<i>Himatanthus obovatus</i> (Müll.Arg.) Woodson	Apocynaceae	-	34	4	11
<i>Myrcia tomentosa</i> (Aubl.) DC.	Myrtaceae	-	-	4	3
<i>Pouteria ramiflora</i> (Mart.) Radlk.	Sapotaceae	23	32	4	4
<i>Annona coriacea</i> Mart.	Annonaceae	13	25	3	5
<i>Antonia ovata</i> Pohl	Loganiaceae	-	5	3	3
<i>Buchenavia tomentosa</i> Eichler	Combretaceae	-	-	3	3
<i>Ouratea hexasperma</i> (A.St.-Hil.) Baill.	Ochnaceae	40	50	3	4
<i>Cordia elliptica</i> (Cham.) Kuntze	Rubiaceae	-	-	2	1
<i>Cybistax antisyphilitica</i> (Mart.) Mart.	Bignoniaceae	2	2	2	2
<i>Emmotum nitens</i> (Benth.) Miers	Emmotaceae	2	6	2	2
<i>Heisteria ovata</i> Benth.	Olaceae	1	1	2	2
<i>Protium heptaphyllum</i> (Aubl.) Marchand	Burseraceae	1	7	2	2
<i>Brosimum gaudichaudii</i> Trécul	Moraceae	6	20	1	1
<i>Casearia sylvestris</i> Sw.	Salicaceae	2	4	1	3
<i>Copaifera langsdorffii</i> Desf.	Fabaceae	-	-	1	1
<i>Dimorphandra mollis</i> Benth.	Fabaceae	2	17	1	6

Species	Family	CT		CR	
		2009	2012	2009	2012
<i>Erythroxylum testaceum</i> Peyr.	Erythroxylaceae	11	12	1	1
<i>Ferdinandusa elliptica</i> (Pohl) Pohl	Rubiaceae	-	-	1	1
<i>Hancornia speciosa</i> Gomes	Apocynaceae	-	1	1	2
<i>Peritassa campestris</i> (Cambess.) A.C.Sm.	Celastraceae	-	1	1	-
<i>Plenckia populnea</i> Reissek	Celastraceae	7	10	1	2
<i>Strychnos pseudoquina</i> A.St.-Hil.	Loganiaceae	5	5	1	1
<i>Aspidosperma multiflorum</i> A.DC.	Apocynaceae	1	2	-	-
<i>Callisthene fasciculata</i> Mart.	Vochysiaceae	6	10	-	-
<i>Caryocar brasiliense</i> Cambess.	Caryocaraceae	3	9	-	-
<i>Couepia grandiflora</i> (Mart. & Zucc.) Benth.	Chrysobalanaceae	27	41	-	1
<i>Diospyros hispida</i> A.DC.	Ebenaceae	2	38	-	-
<i>Enterolobium gummiferum</i> (Mart.) J.F.Macbr.	Fabaceae	-	1	-	-
<i>Eremanthus brasiliensis</i> (Gardner) MacLeish	Asteraceae	1	-	-	-
<i>Erythroxylum daphnites</i> Mart.	Erythroxylaceae	1	1	-	-
<i>Eugenia puniceifolia</i> (Kunth) DC.	Myrtaceae	2	2	-	-
<i>Eugenia</i> sp.	Myrtaceae	1	1	-	-
<i>Euplassa inaequalis</i> (Pohl) Engl.	Proteaceae	-	2	-	-
<i>Guapira noxia</i> (Netto) Lundell	Nyctaginaceae	2	2	-	-
<i>Handroanthus ochraceus</i> (Cham.) Mattos	Bignoniaceae	2	4	-	-
<i>Licania humilis</i> Cham. & Schltld.	Chrysobalanaceae	14	20	-	-
<i>Luehea</i> sp.	Malvaceae	-	1	-	-
<i>Machaerium acutifolium</i> Vogel	Fabaceae	1	14	-	1
<i>Myrcia camapuanensis</i> N.Silveira	Myrtaceae	6	5	-	-
<i>Myrcia multiflora</i> (Lam.) DC.	Myrtaceae	13	13	-	-
<i>Myrcia splendens</i> (Sw.) DC.	Myrtaceae	4	3	-	-
<i>Peltogyne confertiflora</i> (Mart. ex Hayne) Benth.	Fabaceae	1	1	-	-
<i>Pseudobombax tomentosum</i> (Mart. & Zucc.) A.Robyns	Malvaceae	3	3	-	-
<i>Psidium</i> sp.	Myrtaceae	1	5	-	-
<i>Roupala montana</i> Aubl.	Proteaceae	5	16	-	-
<i>Salacia crassifolia</i> (Mart. ex Schult.) G.Don	Celastraceae	1	4	-	-
<i>Salacia elliptica</i> (Mart. ex Schult.) G.Don	Celastraceae	1	2	-	-
<i>Simarouba versicolor</i> A.St.-Hil.	Simaroubaceae	5	9	-	1
<i>Stryphnodendron obovatum</i> Benth.	Fabaceae	1	4	-	-
<i>Terminalia argentea</i> Mart.	Combretaceae	2	9	-	-
<i>Vochysia rufa</i> Mart.	Vochysiaceae	3	5	-	-
<i>Xylopia aromatica</i> (Lam.) Mart.	Annonaceae	-	1	-	-
Total		1,523	2,827	2,171	2,966

Table 3 – Comparison of structural parameters and species composition of the woody vegetation recorded in the *cerrado típico* (CT) and *cerrado rupestre* (CR) in Bacaba Municipal Park, Nova Xavantina, Mato Grosso, Brazil. t_{par} = paired t test; t = t test; and * = significant difference ($p \leq 0.05$).

Parameters	CT 2009	CT 2012	CR 2009	CR 2012
Richness	89	96	78	81
Density	1,523	2,827	2,171	2,966
Basal area	8.70	11.52	13.00	15.17
	2009	2012	CR	CT
	CR x CT	CR x CT	2009 x 2012	2009 x 2012
Density	$t = 2.84; p = 0.001^*$	$t = 0.75; p = 0.46$	$t_{\text{par}} = -5.54; p < 0.001^*$	$t_{\text{par}} = -9.11; p < 0.001^*$
Basal area	$t = 4.42; p < 0.001^*$	$t = 3.98; p < 0.001^*$	$t_{\text{par}} = -11.27; p < 0.001^*$	$t_{\text{par}} = -10.19; p < 0.001^*$

(Figs. 2a; 3a). Higher mean annual recruitment rates and greater gains in basal area were also recorded in the smaller diameter classes at both sites (Figs. 2b; 3b). Negative correlations were obtained at both sites between diameter classes and

mortality, recruitment, and loss and gain rates (Tab. 4). In addition, most of the diameter classes (except 21–24 cm) presented positive net rates of change at both sites. The 21–24 cm class lost more individuals than it recruited, however (Figs. 2c,d; 3c,d).

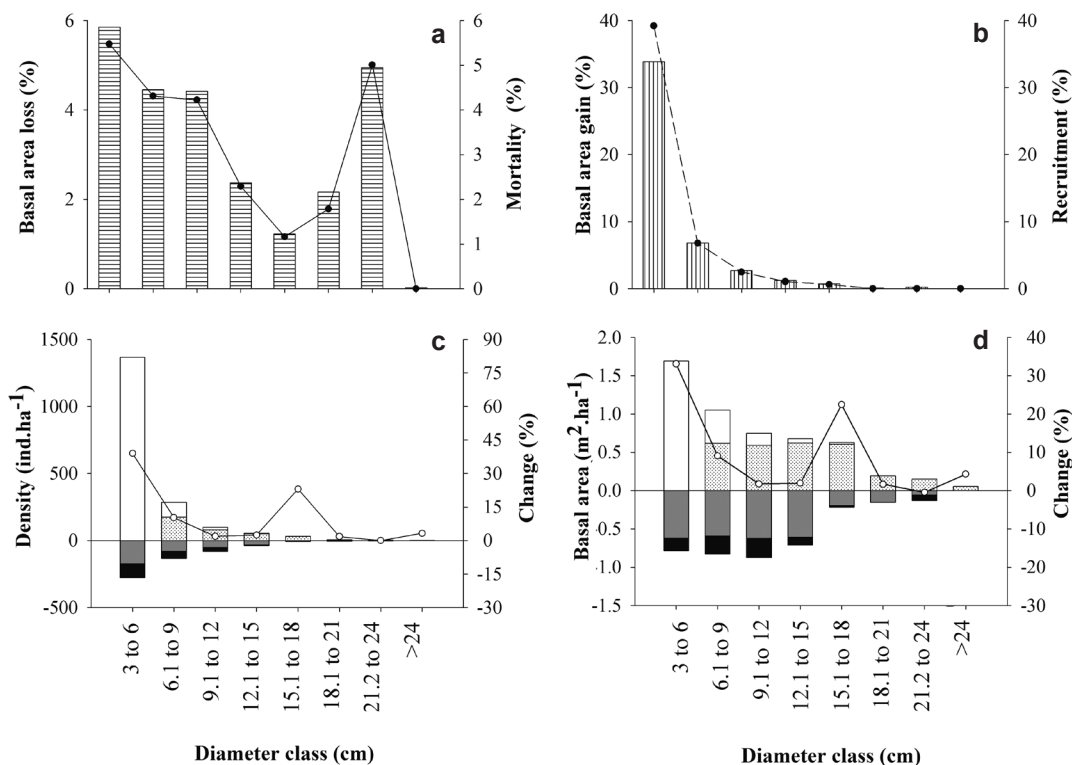


Figure 2 – Structural parameters and dynamics of the woody vegetation in 2009 and 2012 in the *cerrado típico* of the Bacaba Municipal Park, Nova Xavantina, Mato Grosso, Brazil – a. average annual rate of loss of basal area (horizontal stripes) and mean annual individual mortality rate (—●—); b. average annual rate of gain in basal area (vertical stripes) and mean annual recruitment rate of individuals (—●—); c. dynamic parameters in density; d. dynamic parameters in basal area (■ = egress; ■ = dead; ▨ = ingress; □ = recruit; -○- = change).

Table 4 – Structural parameters and dynamic of the woody vegetation in the *cerrado típico* (CT) and *cerrado rupestre* (CR) in Bacaba Municipal Park, Nova Xavantina, Mato Grosso, Brazil. $t = t$ test; R_s = Spearman's correlation; * = significant difference; and ** = significant correlation ($p \leq 0.05$).

Dynamics parameters	CT	CR	Test	Correlation	
				CT	CR
Number of individuals					
Average annual mortality rate (%year ⁻¹)	4.92	6.20	$t = 0.75; p = 0.46$	$R_s = -1.0; p = 0.02^{**}$	$R_s = -0.78; p = 0.05^{**}$
Average annual recruitment rate (%year ⁻¹)	24.35	15.40	$t = -2.85; p = 0.01^*$	$R_s = -1.0; p = 0.02^{**}$	$R_s = -1.0; p = 0.02^{**}$
Reposition time (turnover) (years)	9.85	10.69	$t = 0.54; p = 0.59$	-	-
Half-life time (years)	16.39	15.78	$t = -0.60; p = 0.55$	-	-
Doubling time (years)	3.31	5.60	$t = 2.85; p = 0.01^*$	-	-
Stability time (years)	13.08	10.18	$t = -2.05; p = 0.06$	-	-
Net change rate (% year ⁻¹)	25.00	11.97	$t = -3.08; p = 0.01^*$	-	-
Basal area					
Average annual loss rate (%year ⁻¹)	3.88	2.45	$t = -2.60; p = 0.02^*$	$R_s = -0.98; p < 0.01^{**}$	$R_s = -0.86; p = 0.01^{**}$
Average annual of gain rate (%year ⁻¹)	8.58	3.58	$t = -4.33; p < 0.01^*$	$R_s = -0.98; p < 0.01^{**}$	$R_s = -1; p < 0.01^{**}$
Reposition time (turnover) (years)	15.72	28.24	$t = 3.44; p < 0.01^*$	-	-
Half-life time (years)	21.98	34.92	$t = 2.13; p = 0.05$	-	-
Doubling time (years)	9.48	21.56	$t = 4.34; p < 0.01^*$	-	-
Stability time (years)	12.50	13.36	$t = -0.14; p = 0.89$	-	-
Net change rate (% year ⁻¹)	19.56	5.77	$t = -3.01; p = 0.01^*$	-	-

Discussion

Changes in species richness were small and similar between CR and CT. Overall changes in species richness in the Cerrado biome tend to be small and transitory (Felfili *et al.* 2000; Aquino *et al.* 2007), even in areas that have suffered some kind of disturbance, such as natural fire (Gomes *et al.* 2014; Lopes *et al.* 2009). In addition, these small changes were due to species that occur at low densities, where the death or recruitment of a small number of individuals may easily provoke a decrease or increase in species richness. While the

CT and CR were similar floristically, the two sites were classified separately, indicating the existence of preferential groups of species between sites (Gomes *et al.* 2011).

The greater increase in density and recruitment rates in the CT was reflected in shorter doubling times at this site. In other words, the number of individuals in the CT doubles over a shorter period than in the CR. The similar mortality rates between the CR and CT were reflected in similar half-life times, that is, both sites are reducing in number of individuals within similar periods. In addition, the higher mortality, recruitment, and loss and gain

rates observed in the CT made this community more dynamic in comparison with the CR (Oliveira-Filho *et al.* 1997).

While it was not possible to determine these parameters before the fire (2008), the density and basal area accumulated between censuses (2009 and 2012) indicate that the vegetation at both sites was restructured, with a higher increase in density and basal area being recorded in the CT in comparison with the CR. The higher values recorded in the CT were supported primarily by *Erythroxylum suberosum*, *Kielmeyera rubriflora*, *Heteropterys byrsonimifolia* and *Myrcia lanuginosa*, which occurred at both sites, but increased in density by 50% or more, only in the CT.

The dynamic parameters, although varying between sites, indicate that both communities are recovering from the fire, based on their higher recruitment than mortality, as well as higher

ratios of gain to loss and half-life to doubling times. The positive rates of change found in the present study confirm the recovery of the study communities, as observed by Corrêa & Van Den Berg (2002). Positive patterns of change are usually reported from areas which have not suffered recent disturbance (Henriques & Hay 2002; Mews *et al.* 2011), thus indicating that both the CR and the CT are able to recover from fire damage in approximately three years.

The similar levels of stability found at the two sites (CT and CR) indicate that they require a similar interval of time to recuperate density and basal area, as suggested by Korning & Balslev (1994). Mews *et al.* (2011) also reported longer stability times (years) (number of individuals = 47.01, basal area = 67.52 m².ha⁻¹) in a nearby area of cerrado *sensu stricto* protected from fire, although in this study, a minimum basal diameter of 5 cm was used.

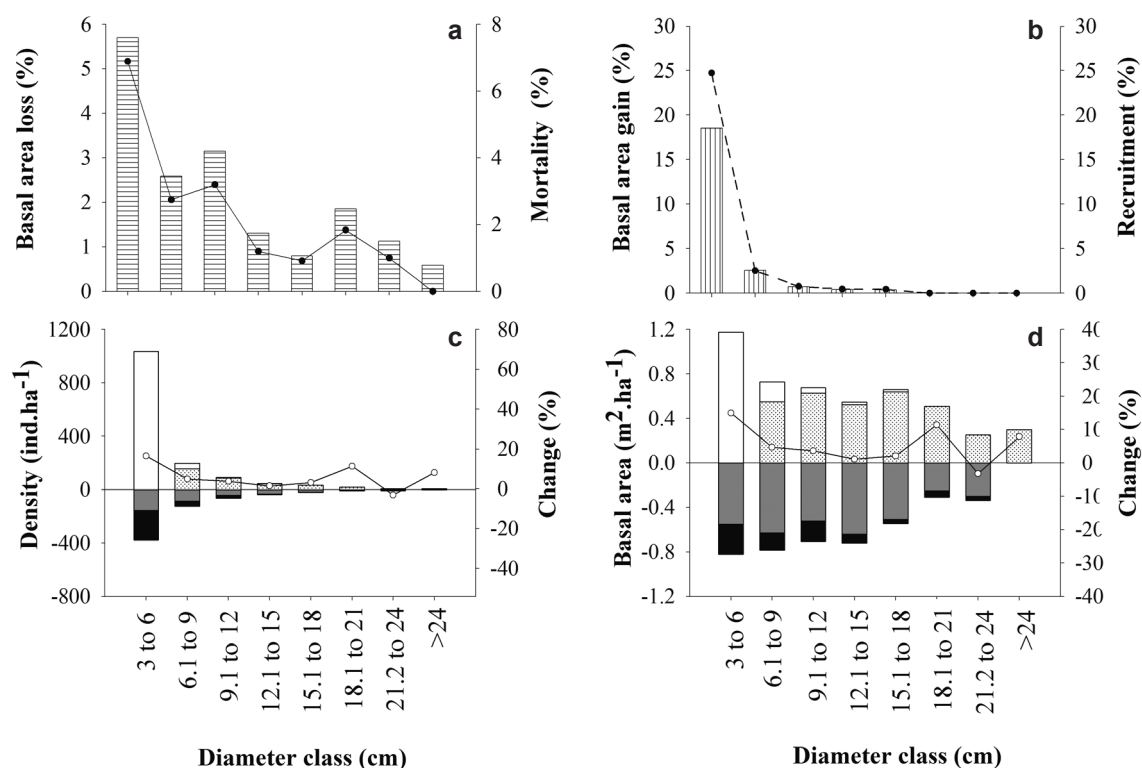


Figure 3 – Structural parameters and dynamics of the woody vegetation in 2009 and 2012 in the *cerrado rupestre* of the Bacaba Municipal Park, Nova Xavantina, Mato Grosso, Brazil. a. average annual rate of loss of basal area (horizontal stripes) and mean annual mortality rate of individuals (—●—); b. average annual rate of gain in basal area (vertical stripes) and mean annual recruitment rate of individuals (---●---); c. dynamic parameters in density; d. dynamic parameters in basal area (■ = egress; ■ = dead; ▨ = ingress; □ = recruit; -○- = change).

The negative correlations between diameter classes and both mortality rates and the reduction in basal area recorded at both sites indicate a greater susceptibility of smaller individuals, possibly due to occurrence of fire at these sites in 2008. Smaller individuals appear to be more affected by fire because they have thinner bark, less well developed underground reserve organs, and are more exposed to the flames (Miranda & Sato 2005; Miranda *et al.* 2010). Even so, the higher mortality and loss rates recorded in the smaller diameter classes were balanced by the elevated rates of recruitment and gain recorded in these classes, with higher values being recorded in the CT in comparison with the CR.

The differences between the structural (density and basal area) and dynamic (recruitment rate, loss and gain rate, reposition time, doubling time and net change rate) parameters suggest that the difference in substrate between the CT and CR may underpin distinct responses in the dynamics of vegetation. These differences emphasize the need to evaluate these physiognomies separately for the development of future conservation strategies.

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